Indira Gandhi National Open University
School of Sciences

BAQ-001

Basics of Aquaculture

Introduction to Aquaculture

1

"शिक्षा मानव को बन्धनों से मुक्त करती है और आज के युग में तो यह लोकतंत्र की भावना का आधार भी है। जन्म तथा अन्य कारणों से उत्पन्न जाति एवं वर्गगत विषमताओं को दूर करते हुए मनुष्य को इन सबसे ऊपर उठाती है।"

— इन्दिरा गांधी

"Education is a liberating force, and in our age it is also a democratising force, cutting across the barriers of caste and class, smoothing out inequalities imposed by birth and other circumstances."

— Indira Gandhi

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BASICS OF AQUACULTURE

Block

1

INTRODUCTION TO AQUACULTURE

UNIT 1
Definition and Scope of Aquaculture 7

UNIT 2
History and Development of Aquaculture 21

UNIT 3
Global Scenario of Aquaculture 35

UNIT 4
General Considerations for Aquaculture 51

UNIT 5
Prospects of Aquaculture for Future Development 61

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BASICS OF AQUACULTURE

Most commonly aquaculture is the term used for the rearing of aquatic organisms under controlled or semi-controlled conditions. In much simple words, aquaculture is underwater agriculture. In a broad sense, aquaculture includes culture of fishes, crustaceans, molluscs and other aquatic organisms and plants as well, for their commercial production.

This course is the first among the six courses that make up the Diploma in Aquaculture and comprises six blocks. The term aquaculture used here encompasses both salt and fresh water rearing. The word "mariculture" has been used to distinguish species that are reared in brackish and marine environment. No such word exists for 'freshwater aquaculture'.

Aquaculture that is infact, the art and science of rearing aquatic organisms has been practiced for million of years. Initial mention of carp culture was made in China some 3500 to 4000 years ago. The Japanese reported farming of oysters about 3000 years ago. Despite its long history, application of scientific method to aquaculture production is a recent phenomenon all over the world as well as in India and systematic aquaculture practices developed only during the 20th century. There are several economic varieties in demand all over the world but a very little percentage of it is suitable for culture. Before beginning the aquaculture practice, selection of species for culture, availability of technology for its culture, input and infrastructure facilities, availability of investment, target group and also environmental considerations both suitable for aquaculture and for the surrounding ecosystems should be considered. Apart from these, proper attention should be paid for the constraints if any, and also the future prospects for the species and culture technology.

As air is environment for us, water is environment for aquatic organisms. As a medium to live in, water presents several advantages such as its density, its buffering nature, viscocity, heat capacity and specific gravity. Aquatic environment includes various stages of stagnant and running water bodies, both fresh water and salt water e.g. rivers, streams, lakes, ponds, swamps, estuaries, backwaters and ocean. For practicing aquaculture in any of the aquatic environments an understanding of water quality and its management is necessary. Although water quality includes physical parameters i.e., density, depth, temperature, light, chemical parameters i.e., dissolved gases and solids and biological parameters i.e., the microbes, plankton, benthos, macrovegetation and macrofauna. All these physico-chemical and biological parameters show a pronounced inter-relationship in the form of food chains and food web. All parameters are related to each other so closely that a change in one parameters brings changes in several other related parameters.

Different aquatic ecosystems show different levels of nutrient availability and light exposure and also different levels of productivity. Solar energy is converted into organic substances through the process of photosynthesis, also termed as 'primary productivity'. Primary productivity leads to secondary and tertiary productivity through consumer chains. On the basis of productivity water bodies are classified into oligotrophic, eutrophic and dystrophic.

In every one's views aquaculture is a wise use of aquatic resources. Owing to its location in tropical and subtropical belt of the earth, India has vast and varied water resource potential including major riverine systems, reservoirs, floodplains lakes, ponds, tanks, brakishwaters, paddy fields, inland saline water areas and a long coastline offering tremendous scope for the development of different forms of aquaculture practices. These vast aquatic resources can be well exploited by culturing different aquatic species, for which culture technology and its economical viability studies are available. The candidate species suitable for aquaculture include fishes, crustaceans, molluscs and seaweeds.

Most of the aquaculture is practiced on land or near shore portions of water bodies. Mariculture in open ocean is not well exploited. During last few decades although, conventional methods of aquaculture i.e. ponds, pens cages and integrated aquaculture are being practised, slowly non-conventional methods of aquaculture viz. aquaculture in running water, in recirculatory system, greenhouse aquaculture, waste water aquaculture, recreational aquaculture and aquaculture using raft, pole, rope and tray are not uncommon. Recently, a concept of aquaranching also has come into practice, specially Indian reservoirs hold immense potential for exploring their productivity through aquaranching, which is an art of stocking and recapturing technique of aquatic organisms from open waterbodies. Aquaculture is practised at different levels i.e., extensive, semi-intensive and intensive and occasionally industrial aquaculture.

The aim of aquafarming is not complete until the crop is harvested to its maximum capacity. Depending on the species cultured and size at harvest, different types of nets and fishing devices are used. A guiding principle for aquaculturists is that their job is not complete until the product is consumed. Aquacrops are sold fresh as well as in different processed forms viz. freezing, canning, sausages, freeze drying, smoking etc. Apart from the major products there are several by-products of aquafarming, which have an entirely different market demand. Fish or shellfish farmers should not only be concerned about keeping the animals alive and growing well, they also need to ensure that when the product is marketed it represents the best possible quality. This is not only under the control of the aquaculturist. Maintaining high quality in the final product is possible if that product of excellent quality reaches the processing plant.

Therefore, it is necessary to have knowledge of quality control processes. Knowledge and information alone are useless unless they can be applied. Aquaculture is a bright spot with great potential. Its future depends on those who choose aquaculture as a vocation. The last block of this courses sets the stage for those who make this choice. We hope you will make the best use of this material and equip yourself with the skills available in this field.

BLOCK 1 INTRODUCTION TO AQUACULTURE

Today aquaculture comprises much more than the rearing of fish in ponds or rice fields. Rather than fishing or hunting, which entail the harvesting of fish or animals from an open or common access resource, aquaculture involves tenure and ownership. A number of different aquaculture systems have evolved for the cultivation of large variety of aquatic organisms in marine, brackish and freshwater environments. The past two decades (1980-2000) have seen the growth of the aquaculture industry from an experimental stage to a fully grown sub-sector. Aquaculture has expanded in number of countries world over, but particularly in Asia where the bulk of world production comes from.

The first block introduces you to aquaculture. In this block you will study about the scope and objectives of aquaculture, the global scenario, history and development of aquaculture. Important considerations, constraining factors and future prospects in the development of aquaculture are dealt within this block.

There are five units in this block. Unit 1, the first unit in this block deals with definition and scope of aquaculture. Aquaculture can be defined as farming of aquatic fauna and flora for food, fun and fancy. FAO defines aquaculture as **"the farming of aquatic organization including fish, molluscs, crustaceans and aquatic plants"**. Aquaculture is conducted in all the three types of aquatic environments i.e. fresh water, brackish water and sea water. Freshwater aquaculture is carried out either in fish ponds, fish pens, or fish cages. Brackish water aquaculture is done mainly in fish ponds located in coastal areas. Marine culture employs either fish cages or substrates for molluscs and seaweeds such as stakes, ropes and rafts. Aquaculture includes not only 'fish culture' but cultivation of other animals and plants. Aquaculture has immense scope for the betterment of mankind. Fish provides protein rich diet as fishes are possessed with essential amino acids. Aquaculture provides employment and is a source of earning foreign exchange.

Unit 2, the second unit in this block deals with history and development of aquaculture. Aquaculture is said to have a history of about 4000 years. In India it appears to be of recent origin. Aquaculture is practised in several ways i.e., pond culture, pen culture, cage culture, integrated aquaculture and so on. In India, during post-independence period, there is expansion of fisheries development activities. The earliest form of aquaculture is pond culture. Pen culture is of recent origin.

Unit 3, the third unit in this block explains the global scenario of aquaculture. Aquaculture has been a worldwide phenomenon. Aquaculture's contribution to world fishery production shows a consistent increasing trend and it has attained its position as one of the fastest growing food production activities in the world. Factors related to water quality, soil type and water circulation are important for the selection of cage/pen sites. In integrated fish farming freshwater fish culture is integrated with the farming of crops.

Although cultured fish and shellfish contribute significantly to total fishery production, aquaculture activities are dominated by carps in China and India, oysters in Japan and France and millet fish in Indonesia. Global aquaculture maintains its dominance in both weight and value by freshwater finfish production. Although crustaceans contribute only 4% of the production by weight, value-wise, they contribute 18% of the total.

Unit 4 tells you about general considerations for aquaculture. Development of aquaculture depends on technology availability, input and support facilities, environmental considerations and fund availability. Choice of animal and plant species is one of the important consideration for aquaculture. Not all fishes, prawns or shrimps are suitable for aquaculture. Some species are most appropriate for commercial aquaculture and some are suited for pen and cage culture. Possibilities of disease outbreak, scarcity of water and short supply of feed ingredients are main constraining factors for aquaculture development.

Unit 5 deals with prospects of aquaculture for future development. In sharp contrast with the 10,000-year-old history of traditional agriculture much of the aquaculture activities have developed only during last 3 to 4 decades. There is a serious lack of entreprenual knowledge and experience in aquaculture. Competition for land and water often becomes constraining factor. Inspite of these negative reflections, the future prospects for aquaculture are very bright. Major emphasis of future development will be on shift from extensive to semi intensive system, ranching of open waters, and stress on sewage-fed aquaculture and transfer of technology.

Objectives

After studying this block you should be able to:

- define aquaculture,
- highlight the various forms and methods of aquaculture,
- describe the origin of aquaculture,
- explain history of aquaculture in India,
- discuss the contribution of aquaculture in world's fishery production,
- explain a comprehensive picture of aquaculture activities in different regions of the world,
- appreciate the site specificity of various aquaculture technologies and its varied approaches for adoption,
- explain the importance of environmental considerations in the context of present day aquaculture,
- highlight the aspects for future development of aquaculture, and
- identify the right approach for tapping the full potentials of aquaculture.

UNIT 1 DEFINITION AND SCOPE OF AQUACULTURE

Structure

1.1 Introduction
  Objectives
1.2 What is Aquaculture?
1.3 Aquaculture and Agriculture
1.4 Forms of Aquaculture
1.5 Species for Aquaculture
1.6 Methods of Aquaculture
1.7 Operational Scales of Aquaculture
1.8 Scope of Aquaculture
  Best Option to Capture Fisheries
  Meeting the Requirement of Proteinous Diet
  Employment and Income Generation
  As an Effective Tool for Recycling Municipal Sewage
  Resource Enhancement of Open Waters
  Other Uses of Aquaculture
1.9 Summary
1.10 Terminal Questions
1.11 Answers

1.1 INTRODUCTION

Aquaculture is a new name for what once we called 'fish culture'. Today, aquaculture includes not only culture of fishes but also a number of plants and animals that are cultivated in water. Aquaculture is conducted in all the three types of aquatic environments i.e., fresh water, brackish water and sea water. Aquaculture continues to increase in volume and value of output in many countries of the world, filling the gap between the supply and demand for fish and fishery products, improving nutrition, and contributing to the household economy, particularly in rural areas. There is immense scope for the betterment of mankind through aquaculture.

Objectives

After studying this Unit, you should be able to:

- define aquaculture,
- differentiate between aquaculture and agriculture,
- highlight the various forms and methods of aquaculture,
- appreciate the other usage of aquaculture besides producing nutritious food, and
- deliberate upon the future scope of aquaculture.

1.2 WHAT IS AQUACULTURE?

Aquaculture can be defined as **farming of aquatic fauna and flora for food, fun and fancy.**

The word **aquaculture** is relatively new to the English language. It is actually a new name to what once we called **fish culture**. In the beginning, it was only fishes which were cultivated in waters. Therefore, "fish culture" was a right terminology to express it. Today, not only fishes, but a host of plants and animals are cultivated in waters. Hence, instead of fish culture, **aquaculture** is considered as a more befitting nomenclature for the same.

1.3 AQUACULTURE AND AGRICULTURE

The word aquaculture rhymes well with agriculture. Semantically, also they sound alike i.e. what agriculture is on land, aquaculture is in water or more simply, aquaculture is underwater agriculture.

1 hectare = 10,000 sq. metres

One acre-foot is a volume equivalent to one surface acre with a depth of one foot, equal to 325,850 gallons or approximately 2,718,000 pounds of water.

For the sake of definition, one many equate aquaculture with agriculture but in fact, both are quite different. Aquaculture deals with cultivation in a more complex ecosystem than agriculture. In aquaculture, one has to deal with three dimensional space i.e. surface, column and bottom for the different species or organisms that habitually grow at different levels. Thus, a water mass with a surface area of 1.0 hectare when stocked for cultivation in multi-species combination of various aquatic organisms, in effect, becomes a much larger area. The situation is not so in agriculture. Agriculture is product of plants and animals useful to human beings involving soil cultivation and the breeding and management of crops and lives to it. Tenure of production facilities and property rights to produce are as important to the success of aquaculture as land tenure is to agriculture.

1.4 FORMS OF AQUACULTURE

Parts per Thousand is a concentration at which one unit is contained in a total of one thousand units. Sea water (35 ppt) is normally expressed as ppt.

Aquaculture is conducted in all the three types of aquatic environments

i) freshwater i.e. waters having salinity level of less than 0.5 parts per thousand (ppt),
ii) brackish water with salinity range of > 0.5 to 30 ppt and
iii) seawater with more than 30 ppt salinity. The species of flora and fauna inhabiting the three types of water bodies are accordingly called freshwater species, brackish water species and marine species.

Likewise, aquaculture pursuits in the three types of water are called

i) **freshwater aquaculture**,
ii) **brackishwater aquaculture** and
iii) **mariculture** or **sea farming**. Freshwater which is the most extensively used sector of aquaculture, is further divided into two segments
    a) cold waters of higher latitudes having temperature range of less than 18°C and
    b) warm waters of plains having temperature range of more than 18°C.

Aquaculture practices in these waters are, therefore, called coldwater aquaculture and warmwater aquaculture, respectively. Fresh water aquaculture is carried out either in fishponds, fish pens, fish cages or on limited scale, in rice paddies. Brackish water aquaculture is done mainly in fish ponds located in coastal areas. Marine culture employs either fish cages or substrates for molluscs and seaweeds such as stakes, ropes and rafts.

SAQ 1

What are the three types of aquaculture?

....

....

....

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....

1.5 SPECIES FOR AQUACULTURE

Compared to land animals, aquaculture is a much more varied activity mainly because there are many more species of aquatic organisms each with different characteristics for culture in freshwater, brackishwater and marine environments using different methods.

According to one report, there are about 500 aquatic species which are subjects of aquaculture today. These include 314 species of finfishes, 74 of crustaceans, 69 molluscs, 3 rotifers, 2 annelids, 1 echinoderm, 43 algae, 12 sponges, 9 amphibians, 4 reptiles and 2 mammals.

Some finfish and shellfish species dominate the international aquaculture scenario. They include rainbow trout, Atlantic salmon, Pacific salmon, Chinese carps including common carp, tilapias, penaeid shrimps and oysters.

Likewise, there are several species, which owing to their euryhaline nature, are suitable for culture in all the three types of aquatic environments (fresh, brackish and marine). These include red tilapia, milkfish, grey mullet etc.

Euryhaline: able to live in waters of a wide range of salinities, opposite of stenohaline.

A list of principal aquaculture species in Asia is given in Table 1.1 and illustrations of type specimens of major groups are given in Fig. 1.1 (a – n).

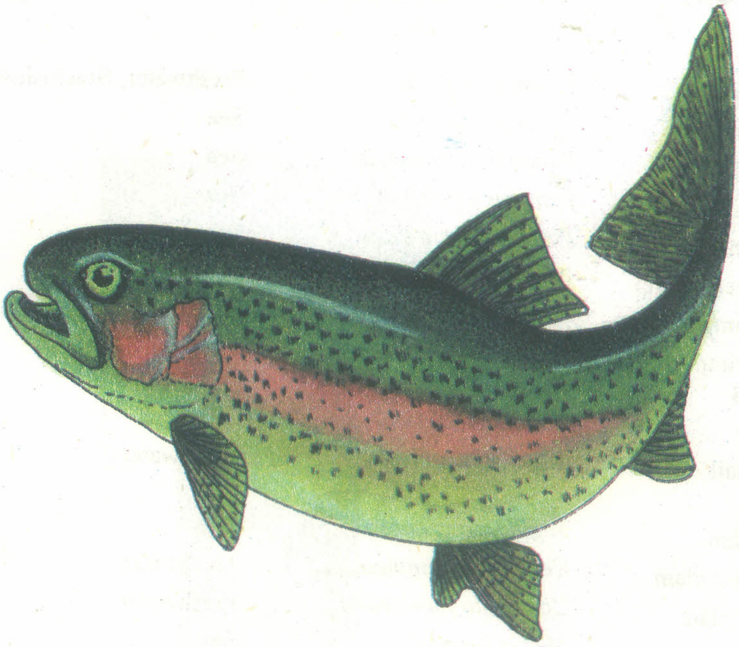
Table 1.1: Principal aquaculture species in Asia.

Common name	Scientific name	Environment of culture
FINFISHES		
• Ayu (Sweet fish)	*Plecoglossus altivelis*	Freshwater
Breams:		
• Black seabream (Porgy)	*Acanthopagrus schlegeli*	Brackishwater, Sea
• Chinese bream (Wuchang fish)	*Megalobrama amblycephalus*	Freshwater
• Red seabream (Porgy)	*Pagrus major (Chrysophrys major)*	Sea
Carps:		
Chinese carps		
• Bighead carp	*Aristichthys nobilis*	Freshwater
• Black carp	*Mylopharyngodon piceus*	Freshwater
• Common carp	*Cyprinus carpio*	Freshwater
• Crucian carp	*Carassius carassius*	Freshwater
• Gold fish	*Carassius auratus*	Freshwater
• Grass carp	*Ctenopharyngodon idellus*	Freshwater
• Silver carp	*Hypophthalmichthys molitrix*	Freshwater
Indian major carps		
• Catla	*Catla catla*	Freshwater
• Mrigal	*Cirrhina mrigala*	Freshwater
• Rohu	*Labeo rohita*	Freshwater
Other carps		
• Calbasu	*Labeo calbasu*	Freshwater
• Bata	*Labeo bata*	Freshwater
• Reba	*Cirrhina reba*	Freshwater
• White carp (kaveri carp)	*Cirrhinus cirrhosus*	Freshwater
• Fringe-lipped carp	*Labeo fimbriatus*	Freshwater

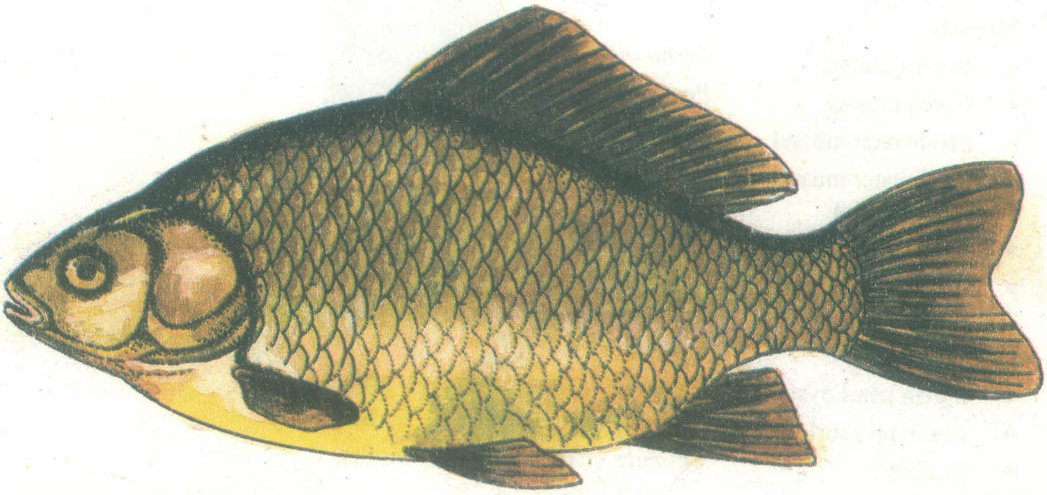
Kursa	*Labeo gonius*	Freshwater
Jelawat	*Leptobarbus hoevenii*	Freshwater
Tawes (Puntius carp)	*Puntius gonionotus*	Freshwater
Catfishes:		
River catfish	*Pangasius sutchi*	Freshwater
Walking catfish	*Clarias spp.*	Freshwater
Japanese catfish	*Parasilurus asotus*	Freshwater
Eels:		
European eel	*Anguilla anguilla*	Freshwater, Brackishwater, Sea
Japanese eel	*Anguilla japonica*	Freshwater
Featherback	*Notopterus chitala*	Freshwater
Grey mullet	*Mugil cephalus*	Freshwater
Groupers:		
Estuarine grouper	*Epinephelus tauvina*	Freshwater, Brackishwater, Sea
Malabar grouper	*Epinephelus malabaricus*	Sea
Polkadot grouper	*Chromileptis altivelis*	Sea
Red grouper	*Plectopomus maculatus*	Sea
Tiger grouper	*Epinephelus microdon*	Sea
Horse mackerel	*Trachurus japonicus*	Sea
Japanese flounder	*Paralichlthys olivaceus*	Sea
Mahseers:		
Milk fish	*Chanos chanos*	Freshwater, Brackishwater, Sea
Mud skipper	*Boliophthalmus chinensis*	Sea
Pearl spot	*Etroplus suratensis*	Brackishwater
Pond loach	*Misgurnus anguillaris*	Freshwater
Puffer (Tiger puffer)	*Sphaeroiders rubripes*	Sea
Rabbit fish	*Siganus fuscessens* *Siganus canaliculatus*	Sea Sea
Rock fish	*Sebastiscus marmoratus*	Sea
Salmonids:		
Atlantic salmon	*Salmo spp.*	Sea
Pacific salmon	*Oncorhynchus spp.*	Sea
Seabass (cockup)	*Lates calcarifer*	Brackishwater, Sea
Silver sillago	*Sillago sihama*	Brackishwater, Sea
Snakeheads:		
Striped snakehead	*Channa striatus*	Freshwater
Snakehead	*Channa maculata*	Freshwater
Snake-skin gourami	*Trichogaster pectoralis*	Freshwater
Snappers:		
Blackspot snapper	*Lutijanus fulviflamma*	Sea
Emperor red snapper	*Lutijanus sebae*	Sea
Golden snapper	*Lutijanus johni*	Sea
Malabar blood snapper	*Lutijanus malabaricus*	Sea
River snapper	*Lutijanus argentimaculatus*	Sea
Tilapias:		
Blue tilapia	*Oreochromis aureus*	Freshwater
Mozambique tilapia	*Oreochromis mossambicus*	Freshwater
Nile tilapia	*Oreochromis niloticus*	Freshwater
Red tilapia	*Oreochromis hybrids*	Freshwater, Brackishwater, Sea
Red belly tilapia	*Tilapia zillii*	Freshwater
Trouts:		
Brown trout	*Salmo trutta fario*	Freshwater
Rainbow trout	*Salmo gairdnerii*	Freshwater

Tunas:		
Bluefin tuna	*Thunnus thynnus*	Sea
Yellow tail	*Seriola quinquiradiata*	Sea
CRUSTACEANS		
Freshwater prawns:		
Giant prawn	*Macrobrachium rosenbergii*	Freshwater
River prawn	*Macrobrachium malcalmsonii*	Freshwater
Lobsters:		
Long-legged spiny lobster	*Panulirus longipes*	Sea
Mud spiny lobster	*Panulirus polyphagus*	Sea
Ornate spiny lobster	*Panulirus ornatus*	Sea
Painted spiny lobster	*Panulirus versicolor*	Sea
Pronghorn spiny lobster	*Panulirus penicillatus*	Sea
Scalloped spiny lobster	*Panulirus homarus*	Sea
Japanese spiny lobster	*Panulirus japonicus*	Sea
Shrimps:		
Tiger shrimp	*Penaeus monodon*	Freshwater, Brackishwater, Sea
White shrimp	*Penaeus indicus*	Sea
Banana shrimp	*Penaeus merguensis*	Sea
Kuruma shrimp	*Penaeus japonicus*	Sea
Redtail shrimp	*Penaeus penicillatus*	Sea
Green tiger shrimp	*Penaeus semisulcatus*	Sea
Sand shrimp	*Metapenaeus ensis*	Brackishwater, Sea
Brine shrimp	*Artemia salina*	Sea
MOLLUSCS		
Abalone	*Haliotis diversicolor*	Sea
Apple snail	*Ampullarius insularum*	Freshwater
Clams:		
Blood clam	*Tegillarca granosa*	Sea
Freshwater clam	*Corbicula fluminea*	Freshwater
Formosa clam	*Corbicula formosana*	Freshwater
Hard clam	*Metrix lusoria*	Sea
Purple clam	*Soletellina diphos*	Sea
Giant snail	*Achatina fulica*	Freshwater
Mussels:		
Brown mussel	*Perna indica*	Sea
Green mussel	*Perna viridis*	Sea
Freshwater mussel	*Lamillidens marginalis*	Freshwater
Freshwater mussel	*Lamillidens corianus*	Freshwater
Oysters (Edible)		
Pacific cupped oyster	*Crassostrea gigas*	Sea
Portuguese oyster	*Crassostrea angulata*	Sea
Edible oyster	*Crassostrea madrasensis*	Sea
Oysters (Pearl)		
Indian pearl oyster	*Pinctada fucata*	Sea
Black-lip pearl oyster	*Pinctada margaritifera*	Sea
Scallop	*Chlamys nobilis*	Sea

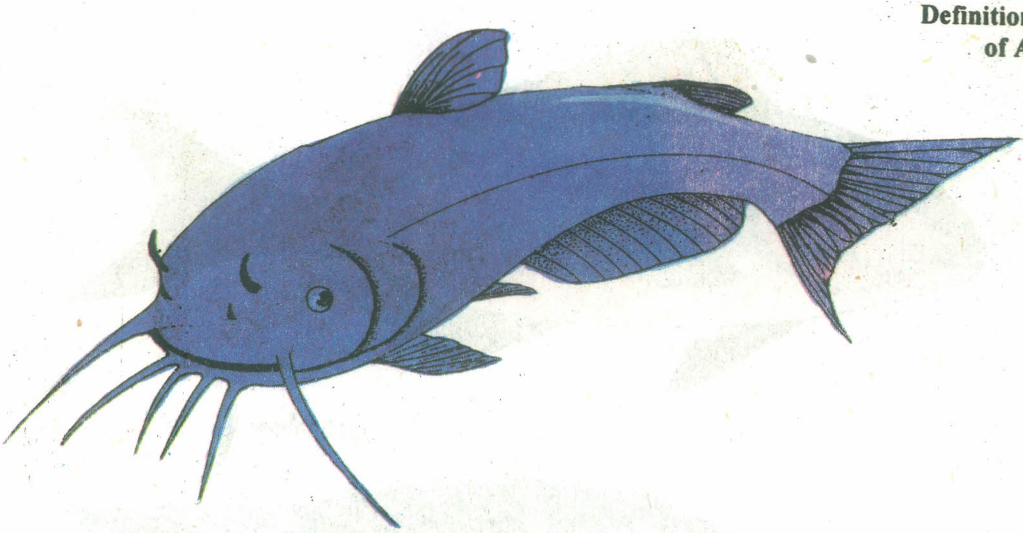
AMPHIBIANS		
• Bull frog	*Rana catasbiana*	Freshwater
• Tiger frog	*Rana tigrina*	Freshwater
REPTILES		
• Soft-shelled turtle	*Trionyx sinensis*	Freshwater
• Siamese crocodile	*Crocodilus siamensis*	Freshwater
• Estuarine crocodile	*Crocodilus porocus*	Freshwater
ECHINODERMS		
• Sea cucumber	*Holothuria scabra*	Sea
AQUA-PLANTS		
• Makhana	*Euryale ferox*	Freshwater
• Singhara (water chestnut)	*Trapa spp.*	Freshwater
• Agarophytes	*Gracilaria spp.*	Brackishwater, Sea
• Green laver	*Monostroma nitidum*	Sea
• Kombu	*Laminaria japonica*	Sea
• Nori	*Porphyra spp.*	Sea
• Wakame	*Undaria pinnatifida*	Sea



(a) Finfish

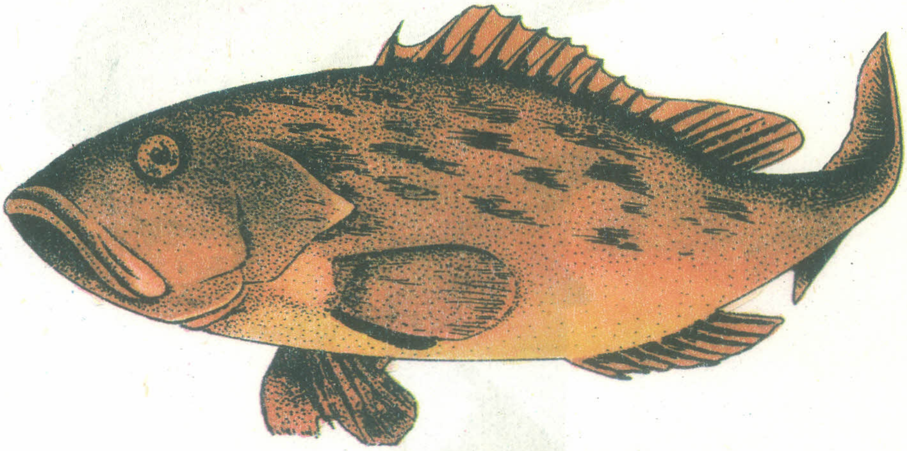


(b) Carp

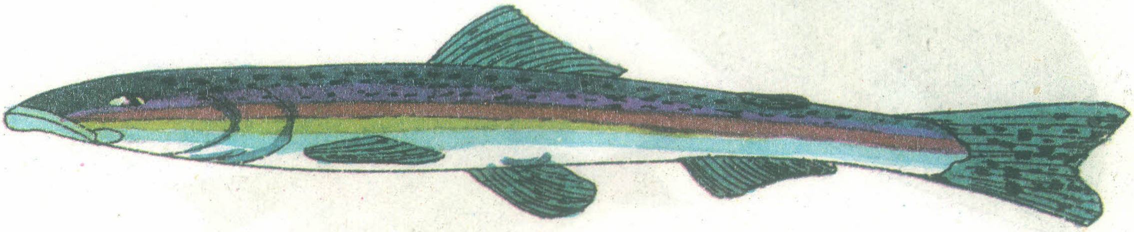


(c) Catfish

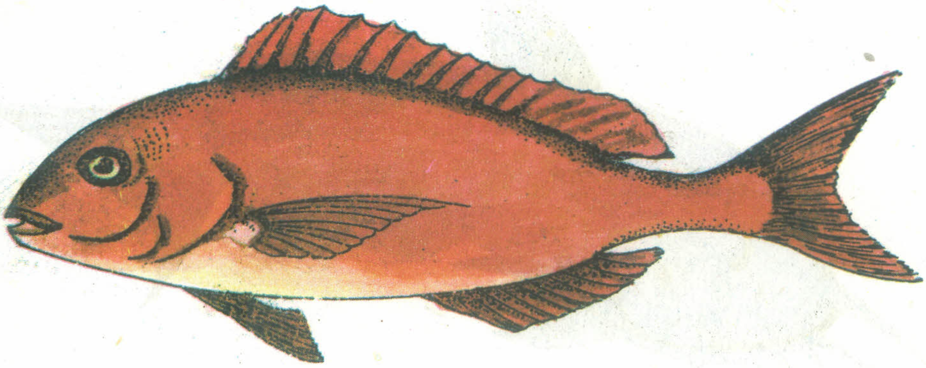
(d) Eel



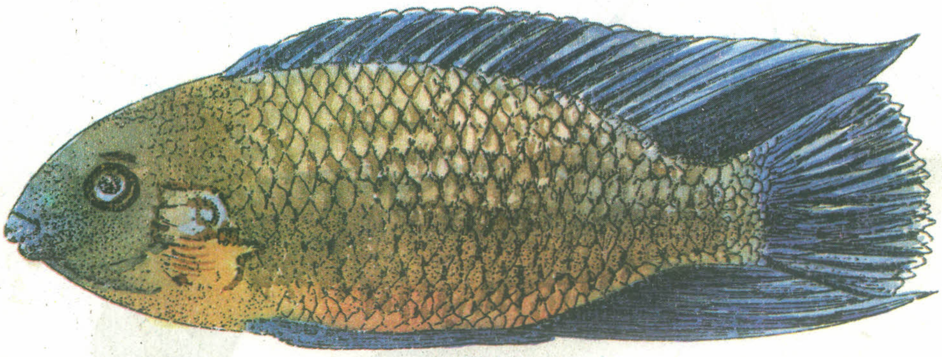
(e) Grouper



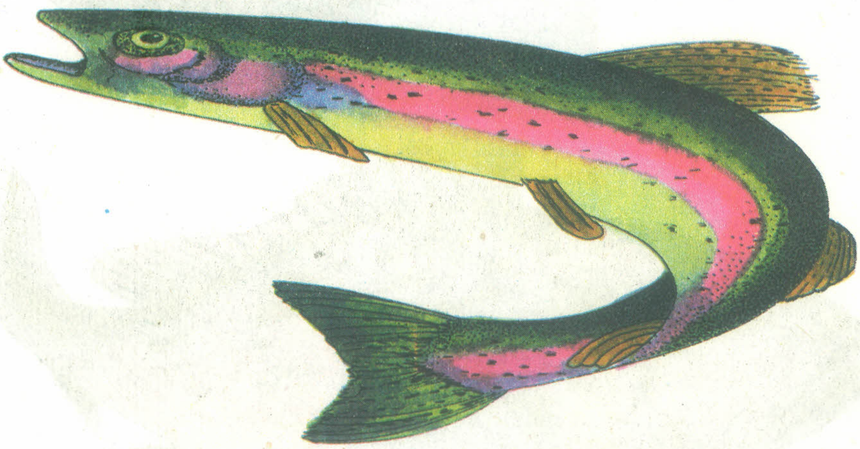
(f) Salmonid



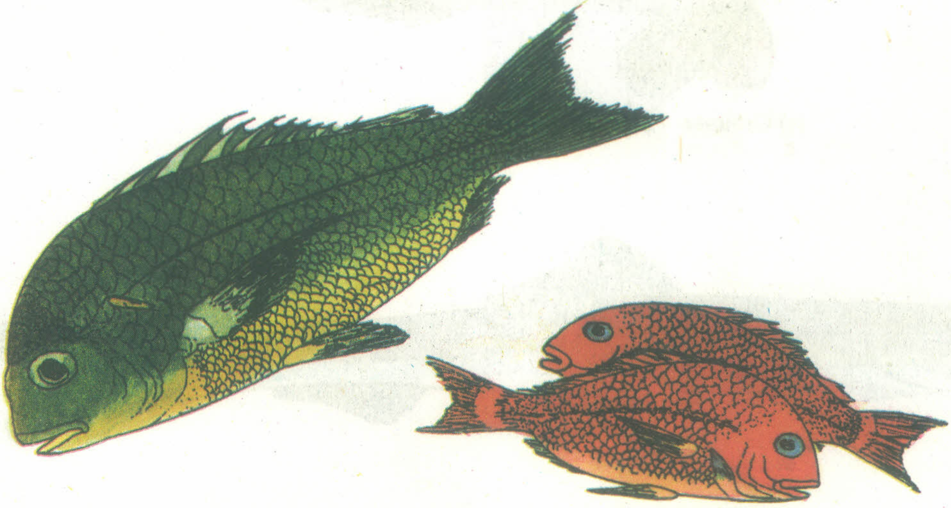
(g) Snapper



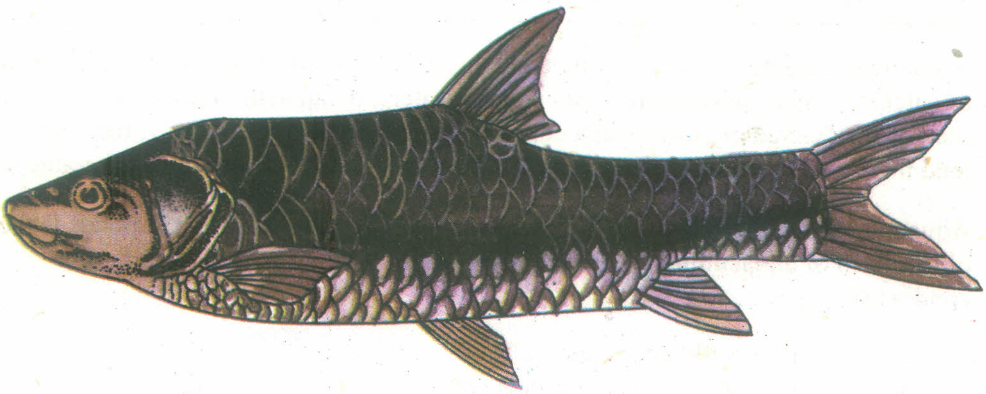
(h) Tilapia



(i) Trout

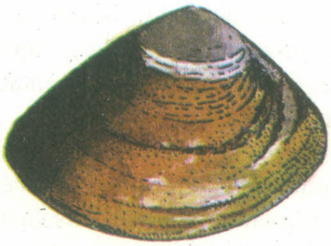


(j) Sea-bream

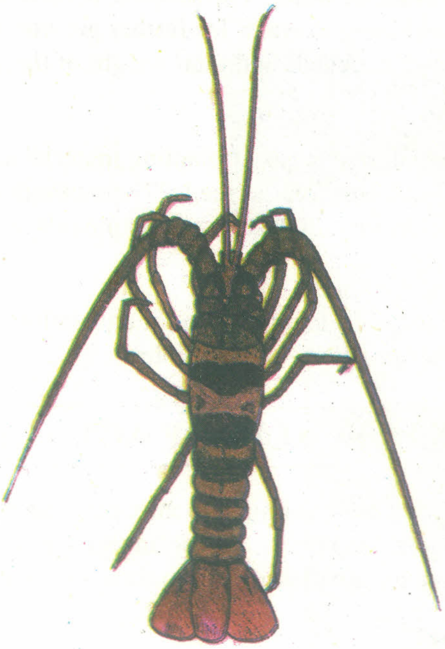


(k) Mahseer

(l) Green Mussel



(m) Fresh water clam



(n) Spiny lobster

Fig. 1.1 a – n: Principal aquaculture species in Asia.

SAQ 2

a) Name two Indian carps as principal aquaculture species.

....

....

b) Name two lobsters as principal aquaculture species.

....

....

1.6 METHODS OF AQUACULTURE

In contrast to capture fisheries where one has only to think about an effective device of catching fishes, prawns etc. from natural waters, in aquaculture one has to stock the seed of the desired organisms in a controlled unit area of a water body, feed them, tend them and then obtain their harvest after the organisms attain the marketable size.

Aquaculture is practised through various methods. Culture of fishes in ponds is the oldest form of aquaculture. There are three ways in which pond aquaculture is conducted

i) aquaculture in still water ponds
ii) aquaculture in running water ponds and
iii) aquaculture in ponds having recirculating water.

Aquaculture in pens is a method in which aquatic organisms are grown in specially erected enclosures in open water bodies. Aquaculture in cages, likewise, is a device in which cultivable organisms are raised in enclosures installed in suspended state in flowing or stagnant waters.
Integrated aquaculture is an innovative approach in which aquatic organisms are grown in combination with agriculture or livestock raising in such a way that the by-product of each system mutually benefits each other.

Molluscs such as oysters and mussels are cultured on suspended ropes or wires hung from rafts floating at the surface of water. The seed i.e. bivalve larvae attached on shells are strung on ropes and hung in water for further growth. Additional floats are added to the raft as the growth proceeds and total weight of the growing biomass increases.

Seaweeds are grown using different types of planting material such as vegetative cuttings, natural seeds, and hatchery-reared seeds. The methods of culture include bottom culture, rope culture, pond culture either in monoculture or polyculture with milkfish, shrimps and crabs.

You will learn about these methods and practices of aquaculture in greater detail in Unit 2 of Block 1 and further in Block 4 of this course.

1.7 OPERATIONAL SCALES OF AQUACULTURE

Aquaculture practices progress from minimal to maximal inputs of external energy, ecosystem manipulation and management. Accordingly, depending on the intensity of operation, aquaculture practices are classified into three operational scales viz.

i) Extensive aquaculture
ii) Semi-intensive aquaculture
iii) Intensive aquaculture

Extensive systems use low stocking densities (5,000-10,000 shrimp post larvae).Extensive aquaculture involves a low degree of control over the environment, nutrition, predator etc. Water change is effected through tidal means, i.e., new water is let in only during high tide and pond can be drained only at low tide. Although, large size ponds are used but little care is taken with regard to its improvement. Natural food organisms, often generated within the culture unit itself, sustain the system. The yield under this system is modest, hardly more than the natural production.

Intensive culture uses very high densities of culture organisms (200,000 – 300,000 shrimp post larvae). Intensive aquaculture, on the other hand, involves high degree of control over the system and high initial costs, a high level of technology and high production levels. Small pond compartments of upto one hectare in size are used.

The stock is an interbreeding sub-population of a species, reproductively isolated to some extent from other populations. Used as a unit for fishery management, however 'stock' refers to a specific population or group of populations of one or more species.

There is a maximum output of product in a minimum of space and water. Virtually, all nutrition for the cultured organisms comes from the use of high quality nutritionally balanced feed. Water quality monitoring, water replacement and aeration is done on daily basis by the use of pumps and aerators.

Semi-intensive aquaculture is a mix of the extensive and intensive aquaculture. Stocking rates are moderately used under this system (50,000 – 100,000 shrimps post larvae).

Semi-intensive and intensive culture systems are more labour – intensive and are costlier to set up and operate. They also carry higher risks of mortalities from disease and poor management. Production and hence financial returns are much more attractive than those from extensive culture. A summary of the comparative features among three main types of culture systems is shown in Table 1.2.

Table 1.2: Summary of comparative features among the three main culture systems.

Parameter	Extensive	Semi-Intensive	Intensive
Species Used	Monoculture or Polyculture	Monoculture	Monoculture
Stocking Rate	Moderate	Higher than extensive culture	Maximum
Engineering Design and Layout	May or may not be well laid-out	With provision for effective water management	Very well engineered system with pumps and aerators to control water quality and quantity
	Very big ponds	Manageable-sized units (up to 2 ha each)	Small ponds, usually 0.5 – 1 ha each
	Ponds may or may not be fully cleaned	Fully cleaned ponds	Fully cleaned ponds
Fertilizer	Used to enhance natural productivity	Used regularly with lime	Not used
Pesticides	Not used	Used regularly for prophylaxis	Used regularly for prophylaxis
Food and Feeding Regimen	None	Regular feeding of high quality feeds	Full feeding of high-quality feeds
		Depending on stocking density used, formulated feeds may be used partially or totally	
Cropping Frequency (crops/year)	2	2.5	2.5
Quality of Product	Good quality	Good quality	Good quality
	Culture species dominant but extraneous species may occur	Confined to culture species	Confined to culture species
	Variable sizes	Uniform sizes	Uniform sizes

1.8 SCOPE OF AQUACULTURE

Future holds immense scope for the betterment of mankind through aquaculture in several ways:

1.8.1 Best Option to Capture Fisheries

The myth that seas and oceans are inexhaustible sources of fishes, prawns etc. has already been proved wrong. Major traditional fishing grounds in a number of developing countries has started showing declining fish catches. Aquaculture, in such a situation, is seen as the best option for meeting the food requirement of growing masses.

1.8.2 Meeting the Requirement of Proteinous Diet

In many countries, specially in the developing world, fish and other aquacrops will serve as the main source of cheap protein to combat malnutrition and under nutrition. This is because fishes possess essential amino acids that are often lacking in cereal protein substitutes. Moreover, fishes are more efficient in converting food into body tissue than poultry or livestock.

1.8.3 Employment and Income Generation

With its growing activities aquaculture is likely to employ a large number of people either directly in the culture activity or indirectly as employees in related or ancillary industries such as seed suppliers, feed suppliers, cold storage etc.

A maritime zone adjacent to the territorial sea that may not extend beyond 200 nautical miles from the baseline from which the breadth of the territorial sea is measured is called Exclusive Economic Zone (EEZ). Within EEZ, the coastal state has sovereign rights for the purpose of exploring, exploiting, conserving and managing natural resources.

Nautical mile is a maritime measure of distance, originally equal to one minute of latitude at the equator (1 nautical mile is equivalent to 1.85 km)

Aquaculture will also serve as an ideal alternative livelihood for fishing communities, more particularly in developing countries where the source of income of fisherfolks has been adversely affected by the over-exploitation of traditional fishing grounds.

Aquaculture will also come to be viewed as an important alternative for those countries whose traditional fishing grounds have been severely reduced by the imposition of the 200 mile Exclusive Economic Zone (EEZ). With the export of high-value species like penaeid shrimps, oysters, seaweeds, etc., aquaculture will serve as an excellent source of earning foreign exchange.

1.8.4 As an Effective Tool for Recycling Municipal Sewage

Increasing population pressure has already started weighing heavy on water supply. During the ensuing decades, the situation is going to worsen further. In such a situation, we shall be hardly left with any option than to learn to use the used water through appropriate treatment. In big cities particularly, generation of sewage is enormous. Of late, it is being increasingly realized that municipal sewage is just not a pollutant but also a nutrient resource. Recycling of municipal sewage through aquaculture is an effective method of retrieving those nutrients.

1.8.5 Resource Enhancement of Open Waters

The resource potential i.e. aquatic flora and fauna of open waters are getting depleted alarmingly due to factors like over-exploitation, environmental degradation etc. Resource enhancement in such waters is possible only by stocking them with hatchery produced seeds of desired aquatic organisms and providing them with appropriate artificial shelters enabling the organisms to guard themselves against natural enemies so that they could reach a size where predation and juvenile mortality are much reduced. The technique, called aqua ranching, holds immense promise for future.

1.8.6 Other Uses of Aquaculture

Aquaculture is not limited to the production of species. Crustaceans and small fishes are often grown as bait for sport and/or commercial fisheries. Ornamental species constitute one of the highest value aquaculture industries.

Some species are grown as food for other food fishes while others are raised for use in laboratory as experimental animals.
Some fishes like grass carp is grown for controlling infestation of noxious aquatic weeds while some other fishes (larvicidal ones) e.g. *Gambusia* and *Poecillia* for mosquito control.

Oysters and freshwater mussels are grown to produce cultured pearls and crocodiles for leather, aqua-mammals (dolphins, whales, seals etc.) for fun and entertainment.

Several algal species are cultured for extraction of chemicals. Seaweeds are important sources of agar and iodine. Some species of red algae are valuable source of carrageenan, an important industrial compound used for improving the quality of a number of products.

Carrageenan is obtained by extraction with water of certain species of the class Rhodophyceae (red sea weed). It is a hydrocolloid consisting mainly of the potassium, sodium, magnesium and calcium sulfate esters of galactose.

SAQ 3

State whether the following statements are true or false.

i) Pen culture is the oldest form of aquaculture.
ii) Fishes possess essential amino acids that are often lacking in cereal protein substitutes.
iii) For aquaculture of sessile invertebrates like oysters and mussels, bottom culture is the most popular method.
iv) Grass carp is grown for mosquito control.

1.9 SUMMARY

In this unit you have learnt that

- For the sake of definition, one may equate aquaculture with agriculture but in practice aquaculture deals with cultivation in a much more complex ecosystem.
- There are about 500 aquatic species which are cultivated in three types of aquatic environments i.e. freshwater, brackishwater and sea water.
- Aquaculture is practised in various forms *viz.* pond culture, pen culture, cage culture, integrated aquaculture, rope culture, raft culture and so on.
- In contrast to capture fisheries where one has only to think about an effective device of catching fishes from natural waters; in aquaculture, one has to stock the seed of the desired organisms in a controlled unit area of water body, feed them, tend them and then obtain harvest after attainment of marketable size.
- Aquaculture holds immense scope for the betterment of mankind in several ways *viz.* as best option to catch fish, meeting requirement of proteinous diet, source of employment and income generation as also earning foreign exchange, as a biotechnological tool for recycling of municipal sewage and resource enhancement of open waters.
- Besides production of food species, aquaculture is also used for culture of bait fishes, live food for aqua hatcheries, herbivorous fishes for weed control, larvicidal fishes for mosquito control, oysters and mussels for pearl culture, crocodiles for leather, aqua-mammals for fun and algae for extraction of chemicals and so on.

1.10 TERMINAL QUESTIONS

1. Define aquaculture. How do you compare agriculture with aquaculture?

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2. Discuss the scope of aquaculture for future.

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3. Besides the production of food species, what are the other uses of aquaculture?

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1.11 ANSWERS

Self-assessment Questions

1. i) Freshwater aquaculture, ii) Brackishwater aquaculture, iii) Mariculture
2. a) Common carp and Goldfish, b) Japanese spiny lobsters and mud spiny lobster
3. i) F, ii) T, iii) F, iv) F

Terminal Questions

1. Aquaculture can be defined as farming of aquatic fauna and flora for food, fun and fancy. Aquaculture deals with cultivation in a more complex ecosystem than agriculture. Aquaculture is underwater agriculture.
2. Aquaculture has immense scope for the betterment of mankind in several ways:
   a) meeting the requirement of proteinous diet
   b) employment and income generation
   c) source of earning foreign exchange
   d) effective tool for recycling municipal sewage
3. Aquaculture is not limited to the production of food. Some fishes are grown for controlling infestation of aquatic weeds while other fishes are used for mosquito control. Several algal species are cultured for extraction of chemicals. Seaweeds are important sources of agar and iodine.

UNIT 2 HISTORY AND DEVELOPMENT OF AQUACULTURE

Structure

2.1 Introduction
  Objectives
2.2 Origin of Aquaculture
2.3 Various Culture Practices
  Pond Culture
  Pen Culture and Cage Culture
  Integrated Aquaculture
  Coastal Aquaculture
2.4 History of Aquaculture in India
  Aquaculture Development during Pre-independence Period
  Aquaculture Development during Post-independence Period
2.5 Summary
2.6 Terminal Questions
2.7 Answers

2.1 INTRODUCTION

Aquaculture is an ancient practice which is said to have a history of about 4000 years. But in India it appears to be an activity of recent origin. The earliest form of aquaculture is culture of fishes in freshwater ponds. Pen culture is of recent origin. In India, development of aquaculture in pre-independence period was not very significant but in post-independence period, there is an expansion of fisheries development activities.

Objectives

After studying this Unit, you should be able to:

- discuss how ancient is the origin of aquaculture,
- explain the origin of each method of aquaculture,
- identify the period of major activities in aquaculture development, and
- appreciate the history of aquaculture in India.

2.2 ORIGIN OF AQUACULTURE

Aquaculture is said to have a history of about 4000 years. Culture of fishes in freshwater ponds is the earliest form of aquaculture. The practice took its roots in China, perhaps in an effort of fulfilling the desire of an emperor to have fish in his daily menu. It is speculated that the techniques for keeping fish in ponds originated in China with fishermen who kept their surplus catch alive temporarily on baskets submerged in rivers or small bodies of water. Another possibility is that aquaculture developed from ancient practices for trapping fish, with the operations steadily improving from trapping-holding-growing and finally into complete husbandry practices. The first known treatise on aquaculture is believed to have been written around 500 BC by Fan Lei, a Chinese politician turned fish culturist. He clearly stated in his book that fish culture existed in China during his time and his fish ponds served as a source of his wealth. Over the years, the practice of pond culture spread to almost all parts of the world and is used for culturing a wide variety of organisms in freshwater, brackish water and marine environments.

The earliest fish to come under the wingfold of aquaculture appears to be the common carp (*Cyprinus carpio*), a native of China. It was subsequently introduced in several countries of Asia and Far East by Chinese immigrants and to Europe during the middle ages for aquaculture in monastic ponds (Box 2.1). Monks in Europe were instrumental in disseminating aquaculture methods because fish were eaten by them during fast. From the 6th Century AD, the common carp lost its popularity in China perhaps due to the fact that the Chinese name of common carp "Lee" sounded identical with the sacred name of the then Emperor "Lee" of Tang Dynasty. During that period, it was inconceivable that "Lee" could be cultured and caught for eating. This led the people to look for other candidate species for aquaculture. The choice finally fell on Chinese carps, namely, grass, silver, bighead and mud carp.

Box 2.1: Nendrum Monastic Site.

In the summer months of 1922, 1923 and 1924 the ruins of the monastery of Saint Mochaoi of Nendrum was excavated and "restored" by H.C. Lawlor MA.

The Nendrum Monastic Site comprises the remains of three concentric cashel walls on a small hill on Mahee (old name Nendrum) Island. The inner enclosure contains the Church, the stump of a round tower and graves. There are many walls of various buildings also between the first and second cashels.

On the shore close to the NE side of the site a substantial stone wall runs parallel to the shoreline for about 120 metres at a distance of about 20 meters out from the high tide line. Lawlor had suggested that this was a fish pond, but it now transpires that it is a mill pond.

Investigation of the so-called fish pond in the summer of 1999 led to the discovery of a stone built tide mill and evidence of its earlier evolution.

Tilapia culture is known to be practised in Egypt almost 4000 years ago. Some people believe that tilapia culture in Africa is older than Chinese carp culture in China.

The husbandry of fish is therefore not a new phenomenon. Ancient practices based on the modification of natural bodies of water on wetlands to entrap young fish in enclosures until harvest, have first evolved into more systematic and scientific methods and techniques.

Other regions of the world have shorter traditions of aquaculture. In North America, it is about a century old, in Africa aquaculture production consists exclusively of tilapia culture in ponds and dates back to 1940s. Aquaculture development is gaining momentum in Australia & New Zealand.

2.3 VARIOUS CULTURE PRACTICES

Culture systems range from extensive to intensive depending on the stocking density of the culture organisms, the level of inputs and the degree of management. In countries where government priority is directed towards increased fish production from aquaculture to help meet domestic demand, either due to lack of access to large water bodies, or over-exploitation of marine or inland fisheries, aquaculture practices are oriented towards production for domestic consumption. You will study about various culture practices in the following sub-sections:

2.3.1 Pond Culture

Pond culture is breeding and rearing of fish in natural or artificial basins. It is the earliest form of aquaculture with its origin dating back to the year of the Yin Dynasty (1400-1137 BC). Pond culture is carried out mostly using stagnant waters but can also be used in running waters especially in highland sites with flowing water. Running water fish culture involves growing the fingerlings to marketable size in earthern ponds using water from rivers, irrigation canals, or plain rain water. The continuously flowing water is advantageous for fish culture as it supplies abundant dissolved oxygen.

Pond layout, design of pond compartments, pond management, pond maintenance are important components of pond culture about which you will study in detail later on in this course.

2.3.2 Pen Culture and Cage Culture

Pen culture implies rearing of aquatic organisms (fish, prawns, molluscs etc.) in enclosures formed by cordoning off areas of open water bodies. Compared to pond culture, pen culture is of more recent origin. The method is said to have originated in 1920s in the Seto Inland Sea, situated between Honshu and Shikoku Islands of Japan. In early 1950s the method was adopted in China for rearing carps in freshwater lakes. In 1970s, the practice was introduced to Philippines for culturing milkfish (*Chanos chanos*) in Laguna de Bay and San Pablo Lakes. From Philippines, the technology was transferred to Indonesia for culturing tilapias.

Pen and cage culture involve the rearing of fish within fixed or floating net enclosures supported by frameworks made of bamboo, wood or metal, and set in sheltered shallow portions of lakes, bays, rivers and estuaries.

The wider popularity of cage culture as compared to pen culture may be due to its greater flexibility in terms of siting the structures. For example, cages may be installed in bays, lagoons, straits and open coasts as long as they are protected from strong monsoonal winds and rough seas. Floating cages, can also be set up in deep lakes and reservoirs, and in rivers and canal systems and even in deep mining pools which could not be used otherwise for culture due to harvesting difficulties.

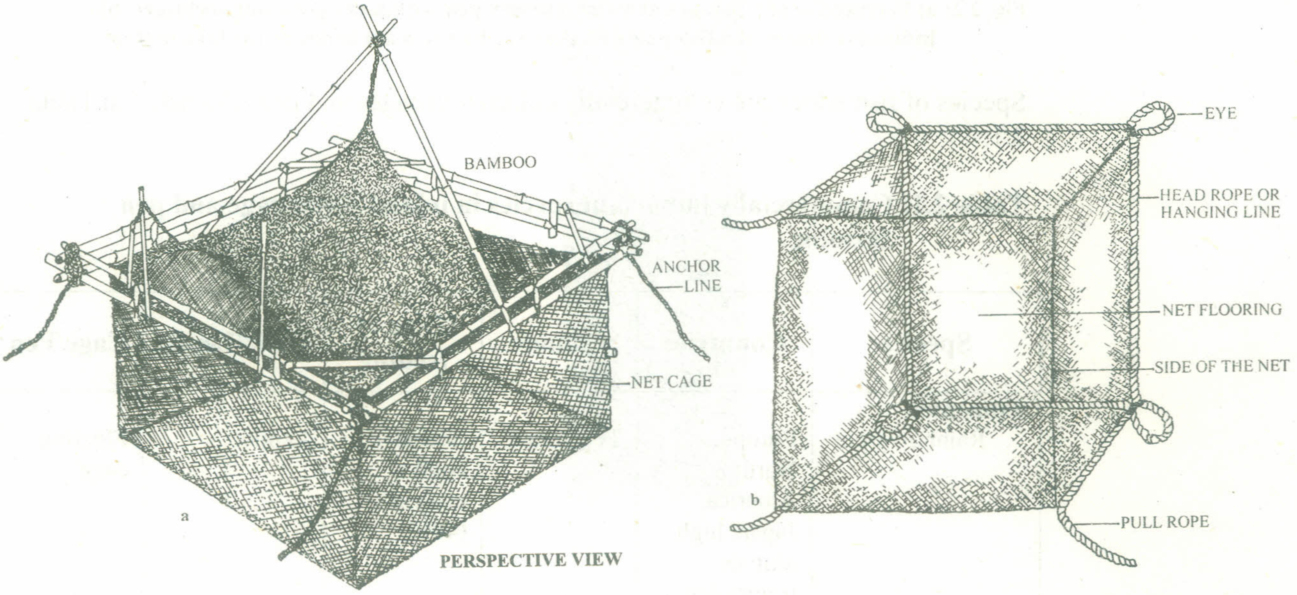

Fig. 2.1: a) Perspective view and b) parts of floating cage.

In general both pen and cage culture have expanded rapidly, especially, over the past two decades vis-à-vis, the decreasing availability of land-based resources for fish culture and an increasing awareness of their merits over traditional pond culture, such as:

i) their applicability in different types of open water bodies,
ii) their high productivity with minimal inputs,
iii) socio-economic opportunities they provide to low-income families in the rural areas held from pen and cage culture are generally high, without supplemental feeding depending on the natural productivity of the water body.

Pens and cages are built around the same basic design concept though they are different in some respects. A cage is like on inverted mosquito net with the cage bottom made of same netting material used for its four sides (Fig. 2.1). Fish pen does not have a net bottom. The edges of its walling/fencings are anchored to the lake bottom (Fig. 2.2).

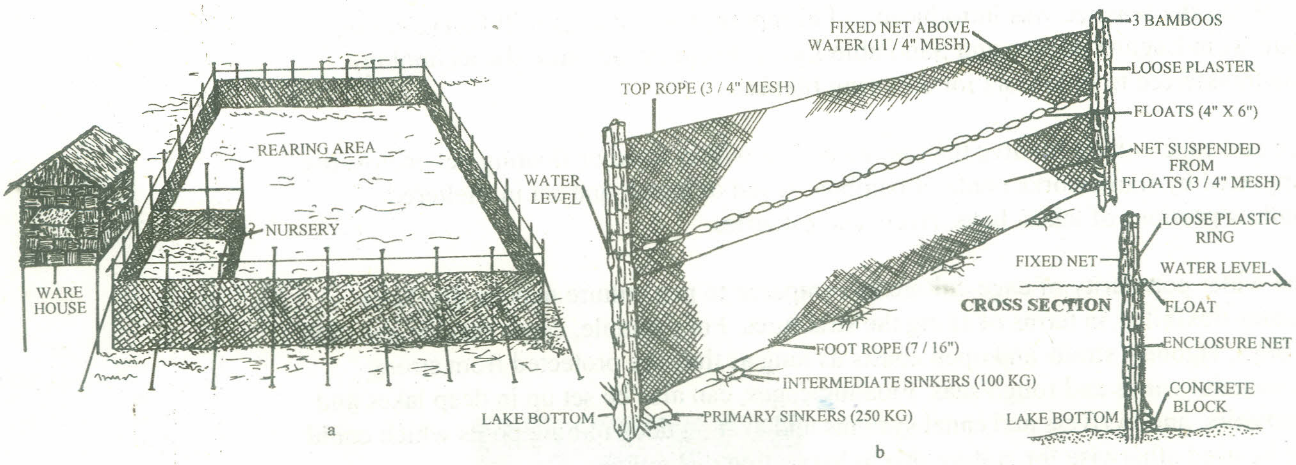

Fig. 2.2: a) Perspective of a fish pen showing nursery pen within the grow-out enclosure. b) Indicative design of a fish pen wall showing how it is anchored on the lake bottom.

Species of fish which are commercially cultured in cages and pens are listed in Table 2.1.

Table 2.1: Commercially important species in inland water cage and pen farming.

Species	Countries	Climate	Type of feeding	Lotic/Lentic	Cage/Pen
Salmonids					
Rainbow trout	Europe, North America, Japan, high altitude tropics (eg Colombia, Bolivia, Papua New Guinea)	Temperate	Intensive, High protein (40%)	Lentic	Floating cage
Salmon (various species) smolts	Europe, North America, South America, Japan	Temperate	Intensive, High protein (45%)	Lentic	Floating cage

Carps Chinese carps (sliver carp, grass carp, bighead carp)	Asia, Europe, North America	Temperate-tropical	Mainly semi-intensive, although also extensive (Asia) and intensive (Europe, North America)	Lotic and lentic	Cages and pens
Indian major carps (*Labeo rohita*)	Asia	Sub-tropical – tropical	Semi-intensive	Mainly lentic	Mainly cages
Common carp	Asia, Europe, North America, South America	Temperate – tropical	Mainly semi – intensive, although also intensive	Mainly lentic	Mainly cages
Tilapias (*O. mossambicus, O. niloticus, etc.*)	Asia, Africa, North America, South America	Temperate – tropical	Mainly semi-intensive, although also intensive	Mainly lentic	Mainly cages
Catfishes Channel catfish	North America	Temperate – sub-tropical	Intensive	Lentic	Floating cages
Clarias spp.	Southeast Asia, Africa	Tropical	Semi-intensive	Lotic and lentic	Floating cages
Snakesheads *Channa* spp. *Ophicephalus* spp.	Southeast Asia	Tropical	Semi-intensive/ intensive	Lotic and lentic	Floating cages
Pangasium spp.	Southeast Asia	Tropical	Semi-intensive	Lentic	Floating cages
Milkfish	Southeast Asia	Tropical	Semi-intensive	Lentic	Pens

Cage culture is a method of raising aquatic organisms inside a cage like enclosure installed in suspended state in ponds, rivers, bays, estuaries and seas. The practice in reported to have originated some two centuries ago in Kampuchia where it was a sort of general practice in the Great Lake areas to hold commercially important fishes like *Clarias* spp. in bamboo baskets to be sold alive. The cages were trailed in water behind a fishing boat for transport to the markets. Since this often took long time, some of the catches were of smaller size, the fishermen began feeding them with trash fish and kitchen waste. The fish grew well in cages and consequently their market value increased considerably. The practice gradually led to the longer term rearing of fishes in cages.

Cage culture method also developed independently in Indonesia where bamboo cages were used to grow *Leptobarbus holveni* fry as early as 1922. Since then, cage culture has spread throughout the world to more than 35 countries.

2.3.3 Integrated Fish Farming

Integrated aquaculture is a commodity culture practice in which fish and prawn are grown in combination with animals or agricultural crops. The practice is said to have originated in China during the period of Ming Dynasty (14-17 century) consequent to pressure of high population density and limited resources. The practice gradually crept down to South-east Asia together with the migration of ethnic Chinese people but remained largely as a traditional activity of these minority ethnic Chinese people. Further expansion of integrated aquaculture started after the second world war. In several European countries (Germany, Hungary, Czechoslovakia, Poland) where carp was traditionally grown, the system of integrated aquaculture (fish-cum-duck or fish-cum-pig) was introduced in order to boost animal food production. As the empirical Chinese methods were not directly applicable in the European climatic and socio-economic conditions, research work on these integrated approaches was taken up and refinements effected in the technology.

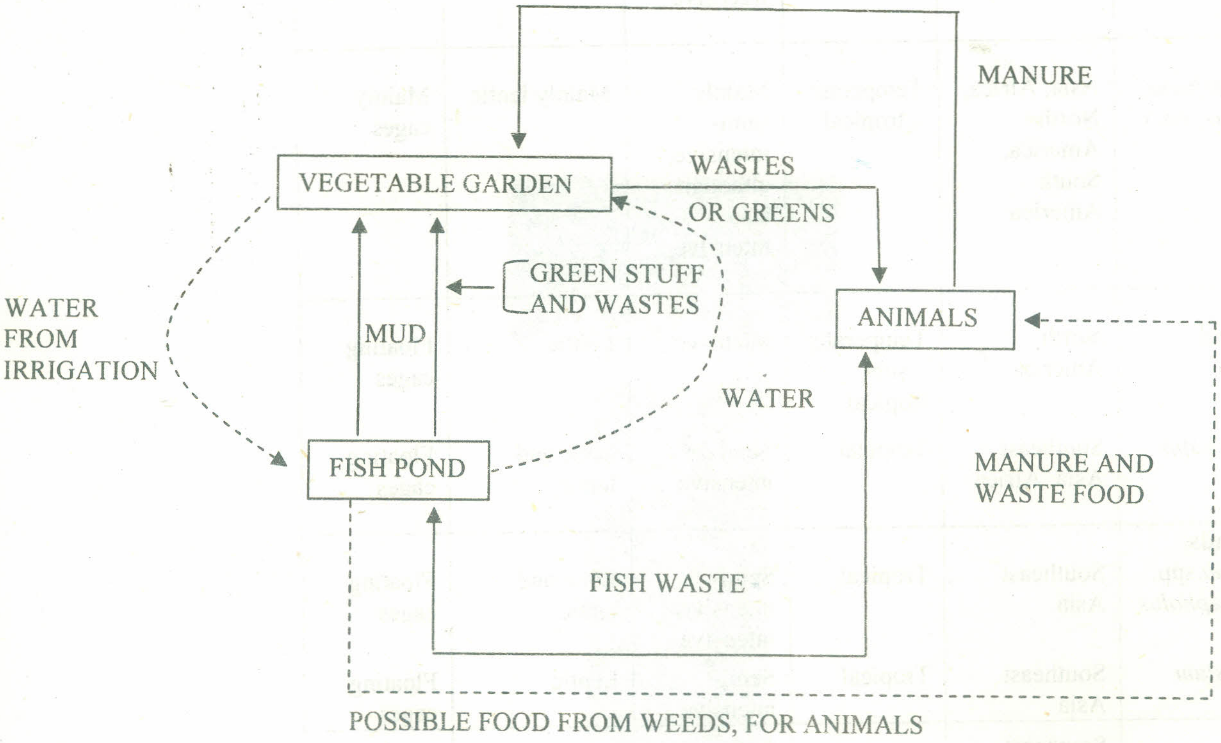

Fig. 2.3: Diagram showing interrelationship among the various components of an integrated fish farming system.

In a number of countries in Asia (e.g. China, Nepal, Thailand, Malaysia, Indonesia) and in some parts of Africa, freshwater fish culture is integrated with the farming of crops, mainly rice, vegetables and animals (usually pigs, ducks and chickens). This leads to greater overall efficiency of the farming system as wastes/by-products or one component are used as inputs on another. For example, poultry or pig manure can be used to fertilise the fish pond and the vegetable garden and the waste vegetables can be fed to the fish and the pigs (Fig. 2.3).

2.3.4 Coastal Aquaculture

The oldest form of coastal aquaculture is probably oyster farming conducted in inter-tidal stretches practised in Japan around 2000 years ago. Aristotle gave a reference of culture in Greece and Pliny of oyster farming done by Romans during 100 BC. The culture of other molluscs, such as mussels and clams, appears to have developed much later.

It is believed that culture of milkfish, (*Chanos chanos*) and other brackishwater species in embanked coastal areas known as *tambaks* originated in Indonesia in the Island of Java during 15th Century. The earliest *tambaks* are reported to have been constructed by convicts who were sent to the coastal areas to work on salt marshes and to guard the coastal fires.

The farming of molluscs and seaweeds in open marine waters has become increasingly popular in a number of countries, especially in the third world countries. Sea farming is generally low cost and labour intensive and could thus involve entire coastal communities.

Bivalves are widely cultured in a number of countries world-wide. Molluscs account for approximately 35% of the total production of coastal aquaculture in terms of gross weight.

The most important species for culture in South-east Asia are mussles, clams, scallops (mainly *Crassostrea* species).

In Japan, the most commonly cultured species include *Crassostrea gigas, C. echinata and C. rivularis.*

Systems are widely distributed in estuaries and bays which receive some run-of from land and have low salinity than the open sea. Three principal methods of system culture are used in the Philippines and Japan:

i) Hanging method
ii) Stake or stick method
iii) Broadcast or sowing method

You will study in detail about these methods later in this course.

Seaweed farming: The culture of the seaweed *Porphyra* is believed to have started as early as between 1596 and 1614 in Hiroshima Bay utilizing pole and net devices originally installed to catch fish. At present, commercially seaweed culture is limited to five countries in East Asia i.e. Japan, Korea, China, Taiwan and Philippines. Seaweeds, aside from being used as food, are important sources of colloids or gels. *Eucheuma,* a red algae is a valuable source of carragennan, an important industrial compound used in stabilizing and improving the quality of a number of products. *Caulerpa* and *Gracilaria* are also economically important algae.

Seaweeds are grown using different types of planting material and methods of culture. These methods are described in detail later in this course.

SAQ 1

Fill in the blanks:

i) The first known treatise on aquaculture is believed to have been written in ....
ii) The earliest fish to come into the wingfold of aquaculture is ....
iii) Pen culture originated in ....
iv) Tambak is an .... area.
v) Aquaculture is said to have a history of ....

SAQ 2

Name two species which are cultured in

i) Pens

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....

ii) Floating cages

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....

2.4 HISTORY OF AQUACULTURE IN INDIA

Aquaculture in India appears to be an activity of ancient origin. Kautilya in his Arthashastra, written around 300 BC, mentioned how fish could be rendered poisonous in tanks during war. The method of fattening fishes in ponds have been described by the King Someshwara in an encyclopedia named "Mansoltara" written by him in 1127 AD.

2.4.1 Aquaculture Development during Pre-independence Period

The 19th Century did not witness any significant development on aquaculture scenario except for collection and transport of carp spawn from rivers in Bihar and West Bengal and spawning of carps in wet and dry bundhs simulated natural environmental conditions of the flooded rivers and inundated fields where carps are bred during monsoon months. Construction work on railways and buildings in plains and deltaic regions of eastern states which necessiated digging for earth resulting in formation of ponds, gave a further fillip to fish culture in the country.

Coastal aquaculture is also quite an ancient practice in India. The earliest forms of coastal aquaculture has been in vogue in the extensive backwaters of Kerala and the Sunderban mangrove swamps of West Bengal for several decades. These practices had been developed by the local farmers to put the low lying saline lands into productive use by raising fishes and prawns. Further, wherever possible, a rotation of agricultural and aquacrops was practised, using the extremely low saline conditions during the monsoon months for paddy cultivation and the medium to high saline period for prawn and fish cultivation.

Early in the 20th Century, with the establishment of Fisheries Departments in certain states, the aquaculture practices got extended to other parts of the country. The first scientifically designed fish farm was constructed by the then Madras Fisheries Department at Sunkesula in Krishna District (now in Andhra Pradesh) in 1911. Gradually, Fisheries Departments were established in other states of the country too. Activities like exhaustive survey for development of aquaculture, studies on bionomics and life history processes of important fishes; aquaculture extension on scientific lines etc. were pursued. Besides food fishes, attention was also paid on culture of larvicidal fishes for biological control of mosquitoes acting as vectors for malaria, filaria, dengue etc.

In India, during pre-independence days, fisheries had been largely looked upon as a source of revenue. The government began taking keen interest in the development of fisheries only in 1944 when a Fish Sub-Committee was appointed to review the position of fisheries in the country and recommended measures necessary for their development. The recommendations of the Committee received immediate attention and, as a first step, some fisheries personnel were appointed at the center to carry out a survey and help the states (then Provincial Government) in formulating and implementing scheme of fisheries development with financial support from the Central Government. Thus, beginning on an ad-hoc basis, the First Five Year Plan (1951-56) placed the development of fisheries on a national footing.

2.4.2 Aquaculture Development during Post-independence Period

A real spurt in aquaculture activities was witnessed soon after India gained independence when almost all the states established either a section or independent Department of Fisheries and initiated action plans on stocking various water bodies with fish seed imported from Calcutta. During those days, fish and fisheries did not figure as a subject of study in any of the Indian universities. The central and state governments had to recruit general graduates and post-graduates of Zoology discipline for manning the managerial posts in the fisheries sector. Since such recruits had no knowledge of the applied fisheries, the government resorted to establishing a series of in-service training centers at various levels. Accordingly, the first move in fisheries training was made during the period of GROW MORE FOOD CAMPAIGN in the country when Government of India in 1974 started two all India fisheries training centers, one for the inland fisheries at Barrackpore in West Bengal and other for marine fisheries at Mandapam Camp in Tamil Nadu. While the latter dealing mainly with marine fisheries has been discontinued, the former dealing with inland fisheries is still continuing under a different set up.

The next major move in fisheries development was made in 1952 when a tripartite agreement was signed between the United Nations, USA and the Government of India. The agreement enabled India to acquire costly equipments for giving a face uplift to its fishing industry and start mechanized fishing operation in coastal waters. This, in turn, led to the establishment of fisheries training centres in all the maritime states of the country.

Following the expansion of fisheries development activities in the country with increasing outlay in the successive Five Year Plans, the Government of India constituted an ad-hoc committee on Fisheries Education in 1959 for assessing the manpower requirements and suggesting measures for providing trained manpower at various levels to give a further boost to fisheries developmental activities. Finding that the existing colleges and universities in India did not provide any formal courses in fisheries, the committee suggested the establishment of a post-graduate training centre for imparting training to district level fisheries officers, deputed by various state governments. Consequently, the Central Institute of Fisheries Education (CIFE) was created by an order of the Ministry of Agriculture on 6 June, 1961 at Bombay. Following the recommendation of the Committee, one more national institute, namely, Central Institute of Fisheries, Nautical and Engineering Training (CIFNET) was established at Cochin in 1963. Besides these, under Indo-Japanese Collaboration programme, the Marine Products Processing Training Centre (MPPTC) came into existence at Mangalore in 1963 for imparting training to fish processing technologists for the upcoming fish processing industry of the country.

Although the system of imparting training in fisheries commenced during the forties, professional programmes of higher fisheries education in the country was started only in 1961 with the establishment of the first College of Fisheries at Mangalore under the aegis of University of Agricultural Sciences, Bangalore, Karnataka. Successful performance of the college helped a great deal in convincing all concerned about the usefulness of having programmes in professional fisheries education at the degree level. Consequently, a chain of fisheries colleges were established under various State Agricultural Universities (SAUs), the total of which presently stands at twelve (Table 2.2).

Table 2.2: Fisheries Colleges offering graduate and postgraduate courses in India.

S.No.	Name and Address of fisheries/colleges	Courses offered (1, 2 and 3*)
1.	College of Fisheries (University of Agricultural Sciences), Mangalore – 575 002	1, 2 and 3
2.	Fisheries College (Tamilnadu Veterinary and Animal Sciences University), Tuticorin – 628 008	1, 2 and 3
3.	College of Fisheries (Orissa University of Agriculture and Technology), Rangailunda, Berhampur – 760 007	1, 2 and 3
4.	College of Fisheries (Kerala Agricultural University), Panagad, Kochi – 682 506	1 and 2
5.	College of Fisheries (Gujarat Agricultural University), Rajendra Bhavan Road, Veraval – 362 265	1 and 2
6.	College of Fisheries (G.B. Pant University of Agriculture and Technology), Pantnagar – 263 145	1 and 2
7.	Fisheries College (Konkan Krishi Vidyapeeth), Dapoli – 415 712, Ratnagiri	1 and 2
8.	College of Fisheries (Rajendra Agricultural University), Muzaffarpur, Bihar	1
9.	College of Fisheries Science (Andhra Pradesh Agricultural University), Nellore – 524 004	1
10.	College of Fisheries (Assam Agricultural University), Raha, Assam	1
11.	College of Fisheries (West Bengal Veterinary and Animal Sciences University), Belgachia Road, Calcutta, West Bengal	1
12.	College of Fisheries Central University for Agricultural Sciences, Tripura	1

* 1 = B.F.Sc.,2 = M.F.Sc. and 3 = Ph.D.

In the initial moves of aquaculture in India, riverine seed or seed produced through bundh breeding used to be the only source of stocking material for fish culture. However, in 1957, a major breakthrough was made when Indian major carps were successfully bred using fish pituitary extract. This facilitated procurement of pure seed of known species for culture purposes. It was indeed a significant development which virtually brought a revolution on aquacultural horizon of the country, so much so that the use of riverine seed for aquaculture came down from over 90% to about 10 to 20%.

A further boost to aquaculture development was provided in 1970s when the Indian Council of Agricultural Research (ICAR), instituted an All India Coordinated Research Project on Composite Carp Culture to develop and demonstrate the viability of composite carp culture technology in different states of the country. Following this, under the rural aquaculture project sponsored by the ICAR/IDRC in Orissa and West Bengal, the viability of the technology in farmers' ponds was further demonstrated.

In 1973, a major national programme of Fish Farmers' Development Agency (FFDAs) was initiated at district level. It provided administrative and infrastructural support, training of beneficiaries, mobilization of inputs and extension support to fish farmers and arranging institutional finance through bank credits. The effort helped in upgrading the technology considerably which, in turn, also helped in improving the productivity of ponds under aquaculture.

An All India Coordinated Research Project on Brackishwater Aquaculture was launched by ICAR in 1973. The project sought to develop semi-intensive technology for mono culture of shrimps (viz. *Penaeus monodon* and *P. indicus*) and fishes (*Chanos chanos, Mugil cephalus, Liza parsia, L. tade, Etroplus suratensis* and *Lates calcarifer*). The project yielded extremely valuable scientific data on a nation-wide basis and led to making specific recommendations on development of brackishwater aquaculture in the concerned states of the country.

With the launching of important social beneficiary schemes like Area Development Approach Programme (ADAP), Brackishwater Fish Farmer's Development Programme, the Bay of Bengal Programme (BOBF) of FAO, the Marine Products Exports Development Authority (MPEDA), etc. the period eighties witnessed a tremendous amount of interest in brackishwater aquaculture.

The role of private sector, particularly in the development of shrimp farming in the eighties was remarkable. Concurrent development of shrimp hatcheries gave a good support to shrimp farming activities during this period. However, a major problem that haunted shrimp farmers was the feed.

Commercial aquaculture of shrimps (largely *P. monodon*) came to be practised in India during early nineties when under the guidance of foreign experts some enthusiastic entrepreneurs tried to initiate the technology of shrimp farming of neighbouring South-east Asian countries. With the liberalization of economy during this period, a significant rush for investing on shrimp farming ventures ensued. The large capital investment and use of modern technology, gave a massive boost to shrimp production in India. However, in the wake of "get rich quick" race shrimp farms mushroomed along the east and west coasts of the country. Many shrimp farms built with high capital investment, were stocked heavily in the hope of reaping richer harvests of shrimps. Heavy stocking necessiated intensive feeding and indiscriminate use of drugs and chemicals which ultimately led to environmental degradation. It became a cause of great worry, so much so that the Supreme Court had to intervene. The situation finally compelled all concerned to look into the possible negative impacts of large aquaculture projects (more than 20 ha water area) on environment before granting them go ahead signal. It is hopefully believed that greater degree of mass awareness will help aqua-entrepreneurs to handle the shrimp farming technology with greater degree of care and caution in coming years.

Diversification in brackishwater aquaculture incorporating cultivable species of fishes like mullets, seabass and crustaceans such as crabs and lobsters is a desirable step to be taken during the ensuing century.

In spite of being gifted with seas on its three sides, Bay of Bengal in the east, Arabian Sea in the west and Indian Ocean in south, sea farming or what is also called mariculture is still in its infancy in India. This is largely because most part of India's coastline is too straight and flat, open to surges of strong winds and heavy tidal waves, thus, making them unconducive for sea farming. However, some bays are there such as in Gulf of Kutch, Konkan coast, Goa, Northern Karnataka, Lakshadweep, Gulf of Mannar and Andaman and Nicobar Islands which could be brought into use for sea farming.

Steps like upgradation of available sea farming technologies and their transfer to coastal fisherfolk through impactful extension techniques are required to be taken to popularize sea farming in India.

SAQ 3

State whether the following statements are 'True' or 'False'.

i) The first scientifically designed fish farm in India came into existence at Harwan in Kashmir.
ii) The 19th Century did not witness any significant development on aquaculture scenario of India.
iii) Indian major carps were successfully bred through fish pituitary extract injection in 1957.
iv) The National Programme of Fish Farmer Development Agency was initiated in 1973.
v) The rural aquaculture project sponsored by ICAR/IDRC was implemented in Andhra Pradesh.

2.5 SUMMARY

You have learnt in this unit that:

- Culture of fishes in ponds is the earliest form of aquaculture and the earliest fishes to come in the wingfold of aquaculture were the common carp in China and tilapia in Egypt.
- While pen culture practice of aquaculture took its origin in Japan in 1920s, the cage culture originated independently at two places, one in Kampuchia and another in Indonesia, almost during the same period.
- The practice of integrated aquaculture originated in China as a result of population pressure and limited resources.
- The oldest form of coastal aquaculture is the oyster farming being practised in Japan for the past 2000 years.
- The culture of milkfish and other brackishwater species came into practice in Indonesia in the Island of Java during 15th century through the convicts who were sent to coastal areas to work on salt marshes and to guard coastal fires.
- The period of 70s saw an upsurge of aquaculture world over after witnessing a long stagnation in marine fish production during 1963 to 1966.
- Mentions made in Kautilya's Arthashastra and other such old literatures reveal that aquaculture in India is an activity of ancient origin.
- While 19th century did not witness any significant development on aquaculture scenario of India, the 20th century from its very beginning proved quite impactful in this respect.
- The first scientifically designed fish farm in India was constructed in 1911 at Sunkesula in Krishna District (now in Andhra Pradesh) by Madras State Fisheries Department.
- A major breakthrough on aquaculture front in country was achieved in 1957 when major Indian carps were successfully bred through the injection of fish pituitary extract and thereby making it easier for the aquafarmers to obtain pure fish feed.
- Commercial aquaculture of brackishwater shrimps came to be practised during early 90s and it suffered a setback on account of its implementation on environment-unfriendly scale.
- Sea farming activities in India is still in its infancy stage.

2.6 TERMINAL QUESTIONS

1) Compare the development of aquaculture in India during pre and post-independence periods.

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2) Write short notes on following:

   i) Origin of integrated aquaculture

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   ……………………………………………………………………………

   ……………………………………………………………………………

   ii) Origin of cage culture

   ……………………………………………………………………………

   ……………………………………………………………………………

   ……………………………………………………………………………

2.7 ANSWERS

Self-assessment Questions

1. a) China
   b) Common carp
   c) Japan
   d) Embanked coastal area
   e) 4000 years
2. i) Milkfish, Chinese carps
   ii) Catfish, Salmonids
3. i) F
   ii) T
   iii) T
   iv) T
   v) F

Terminal Questions

1. In the 19th century, India did not witness any significant development on aquaculture scenario except for collection and transport of carp spawn from rivers in Bihar and West Bengal. The earliest form of coastal aquaculture has been in vogue in the extensive backwaters of Kerala. Early in the 20th century, with the establishment of fisheries departments, the aquaculture practices got extended to other parts of the country. During pre-independence days, fisheries had been largely looked upon as a source of revenue.

   A real spurt in aquaculture was witnessed soon after India gained independence. A tripartite agreement was signed between the United Nations, USA and Govt. of India. Consequently CIFE was created in 1961. MPPTC came into existence under Indo-Japanese collaboration programme. In 1973, FFDA was initiated.

2. i) **Integrated aquaculture:** Integrated aquaculture is a multi-commodity culture practice in which fish and prawn are grown in combination with animals or agricultural crops. The practice is said to have originated in China. Gradually, it crept down to South-east Asia together with the migration of Chinese people. In several European countries where carp was traditionally grown, the system of integrated aquaculture was introduced.

   ii) **Cage culture:** This practice originated in Kampuchia, two centuries ago. Cage culture method also developed independently in Indonesia where bamboo cages were used to grow *Leptobarbus holveni* as early as 1922.

UNIT 3 GLOBAL SCENARIO OF AQUACULTURE

Structure

3.1 Introduction
  Objectives
3.2 Overall Scenario
  Aquatic Products as a Food Source
  Major Commodities of Aquaculture
3.3 Regional Review
  East Asia
  South and Southeast Asia
  Near East and North Africa
  Sub-Saharan Africa
  North America
  Latin America and the Carribean
  Europe
  South Pacific
3.4 Summary
3.5 Terminal Questions
3.6 Answers

3.1 INTRODUCTION

Aquaculture has been a worldwide phenomenon. The number of species is increasing continuously under aquaculture. It has been estimated that the increasingly substantial contribution of aquaculture to total fish production will continue to rise. In the Unit, you will study about aquaculture scenario of the different regions of the world i.e. East Asia, South and South-east Asia and Near East and North Africa, Sub-Saharan Africa and North Latin America, Europe and South Pacific America.

In modern times, not many primary industries have consistently recorded high yearly growth over a period of two decades. Aquaculture has sustained a global growth, continues to grow, and is expected to increasingly fill the shortfall in aquatic food products resulting from static or declining capture fisheries and population increase into the year 2025. Its further growth and development will have to occur under a different socio-economic milieu in the new millennium.

The contribution of aquaculture to world food supply of aquatic products has been increasing over the past 10 years, in comparison to capture fisheries, growing from 15 to 28 percent of total production between 1988 and 1997. As the bulk of aquaculture is rural and subsistence, it plays a major role as a provider of direct and indirect employment to the rural poor and, thereby, to poverty alleviation. In many developing countries, aquaculture provides opportunities for diversification on agriculture farms and productive use to otherwise idle land during certain seasons. The main cause for the upsurge in the sector has been the transformation of aquaculture from an "art" form to a "science". This brought many advantages, ranging from less dependence on wild stock to the development of techniques that optimized yields, such as polyculture, or enabled the achievement of high yields with low inputs. Two major developments also enabled the sector to maintain growth momentum, appropriate institutional frameworks and concerted research and development.

The global and regional trends over the last 20 years in the sector from a number of perspectives, such as production trends, contribution of aquaculture to aquatic food consumption etc., are evaluated. Based on these different trends and in the light of changing socio-economic conditions globally, and in particular, in developing nations, the potential changes in the sector in the new millennium are highlighted.

Objectives

After studying this unit, you should be able to:

- explain the contribution of aquaculture to world's fishery production,
- discuss comprehensive picture of aquaculture activities in different regions of the world,
- identify the aquatic organisms which contribute most significantly in aquaculture.

3.2 OVERALL SCENARIO

Aquaculture has come to long way in the past three decades. This has been a world wide phenomenon, extending into all the continents except Antarctica.

Aquaculture's contribution to world fishery production shows a consistent increasing trend and it is maintaining its position as one of the fastest growing food production activities in the world. Of all the regions of the world, Asia enjoys an obvious dominance as an aquaculture producer of finfish, shellfish and aquatic plants. It accounts for about 80% of world aquaculture production with China and India alone contributing to the tune of about 70%.

The number of species under aquaculture is continuously increasing. An increasing number of countries have taken to aquaculture of crustaceans and molluscs.

A closer scrutiny of the scenario reveals that although cultured fish and shellfish contribute significantly to total fishery production, aquaculture activities in most countries are dominated by a few species such as carps in China and India, oysters and mussels in Japan, the Republic of Korea and France, milkfish in Philippines and Indonesia and so on.

Aquaculture of the four Chinese carps (sliver, grass, common and big head carps) produced largely under semi-intensive and extensive aquaculture systems, dominate finfish production in the world. The prawn and shrimp production recovered well after disease outbreaks which caused production to fall during 1992 and 1993.

Global aquaculture, thus, maintains its dominance in both weight and value by freshwater finfish production. Although crustaceans contribute only 4% of production by weight, value-wise they contribute 18% of the total. The important issues of global synthesis of the aquaculture sector are discussed in the following subsections:

3.2.1 Aquatic Products as a Food Source

Although aquaculture originated at least two millennia ago, it was only since the latter part of the 20th century that it began to make a significant contribution to overall human food supplies, and it is now seen as an important sector for the supply of animal protein. With the increasing awareness of the positive effects of fish consumption on health and well being, the importance of aquaculture in the food sector is destined to grow further. Equally, the sector will also continue to contribute to income generation and livelihoods of significant portions of the global population, mostly the rural poor.

While it is clear that the figures for calorie supply have remained almost unchanged over the last 20 years or so, the contribution to animal protein supply has shown a gradual increase, currently being 16.6 percent. This gradual increase in importance of aquatic food is a reflection of the increase in world fishery production. The per caput fish consumption in 1996 was 15.8 kg/yr, and consumption has grown at an annual rate of 4.7 percent between 1990 and 1995, noting that consumption rates differ significantly amongst continents (Fig. 3.1). Furthermore, there are also large differences of per caput consumption of fish in different regions/countries within a continent. This is best exemplified in the case of Europe, which has an average per caput consumption of around 16.5 kg/yr, but where the European Community (EC) countries consume around 22 kg/yr as opposed to the 6-9 kg/yr reported for the Central and Eastern European countries. You should also note that fish consumption in low-income food–deficit countries (LIFDCs) was only 12.7 kg/yr compared to 19.5 kg/yr in the rest of the world.

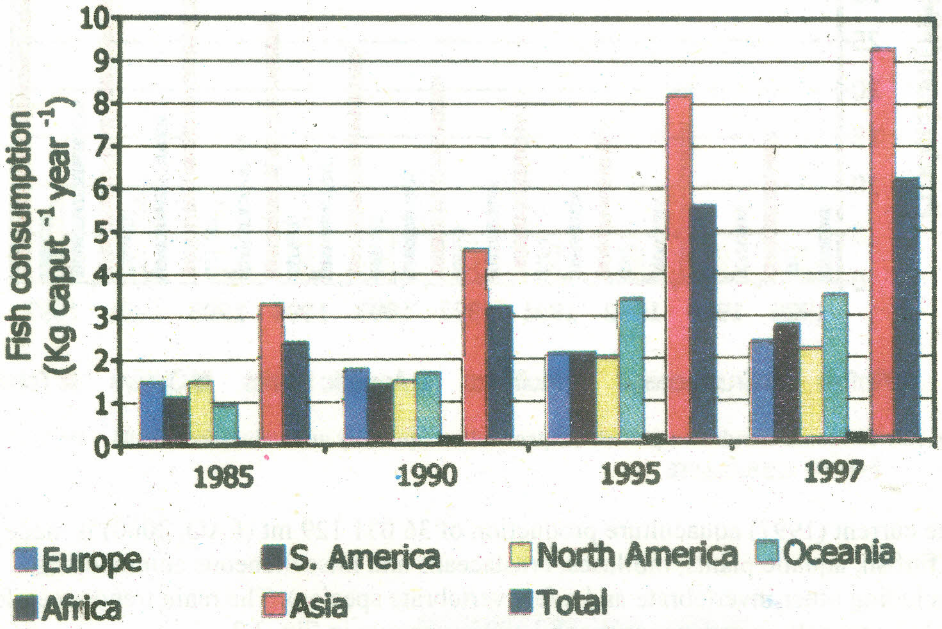

Fig. 3.1: The changes in the per caput fish consumption in the different continents.
Source: www.fao.org

Review of production

World aquaculture in 1997 provided 36 million mt, or 28.8 million mt if one excludes aquatic plants (FAO, 2000), as opposed to 87.1 million mt from the capture fisheries in 1996 (FAO, 1999).

On the other hand and perhaps more importantly, the contribution of aquaculture to the global aquatic food supplies has increased steadily during the last 15 years in comparison to the capture fisheries (Fig. 3.2).

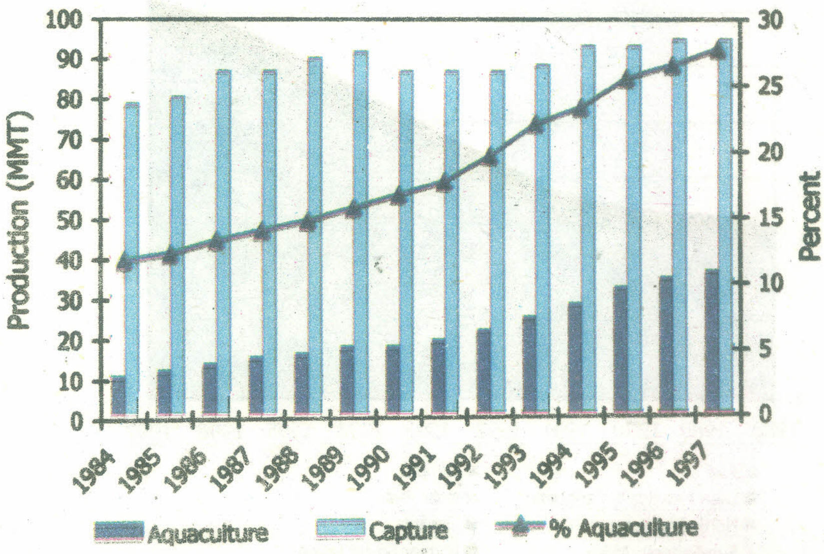

Fig. 3.2: The contributions of capture fisheries and aquaculture to the total aquatic food supply and the percentage contribution of aquaculture (1988 – 1997).
Source: www.fao.org

It is relevant to consider the main reasons for the impressive rise of the sector over the last 20 years. One of the underlying causes can be summarized by the transformation of aquaculture from an "art" to a "science", not only in the approach, but also in the application.

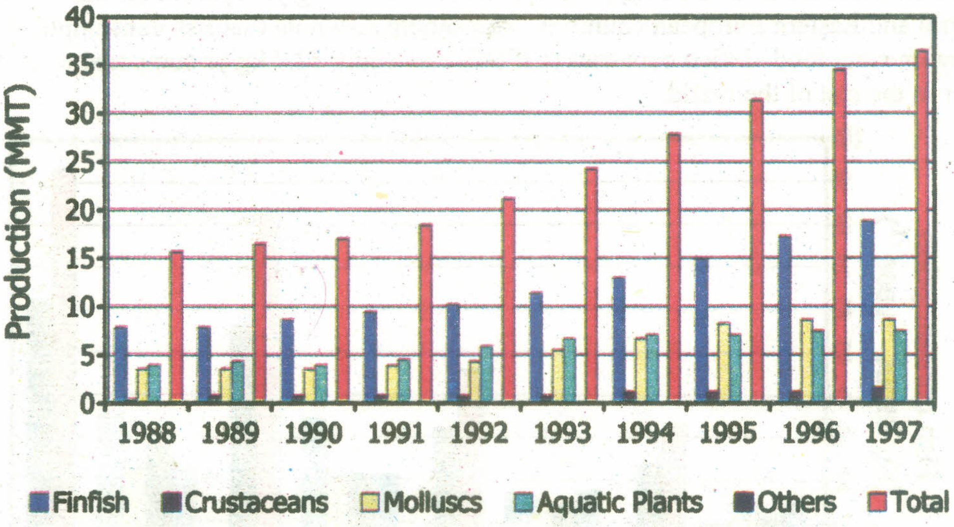

Fig. 3.3: The main trends in aquaculture production (quantity and value) from 1988 – 1997. Source: www.fao.org

The current (1997) aquaculture production of 36 031 129 mt (FAO, 2000) is made up of finfish, aquatic plants, molluscs, crustaceans and miscellaneous commodities (including other invertebrate and a few vertebrate species). The main trends seen for global aquaculture production since 1988 are shown in Fig. 3.3.

It is evident that finfish represents the bulk of the aquaculture production (by volume), contributing about 50 percent of the total, a position that has remained almost unchanged throughout this time (Fig. 3.4). In 1997, finfish (52 percent) was followed by molluscs (24 percent), seaweeds (20 percent) and crustaceans (4 percent). The main change to be seen, however, has been with regard to the culture of aquatic plants, whose contribution has decreased from about 25 percent to 21 percent. Mollusc production has slightly increased its contribution and, after a period of rapid growth in the second half of the 1980s, the crustacean contribution stabilized at around 4 percent.

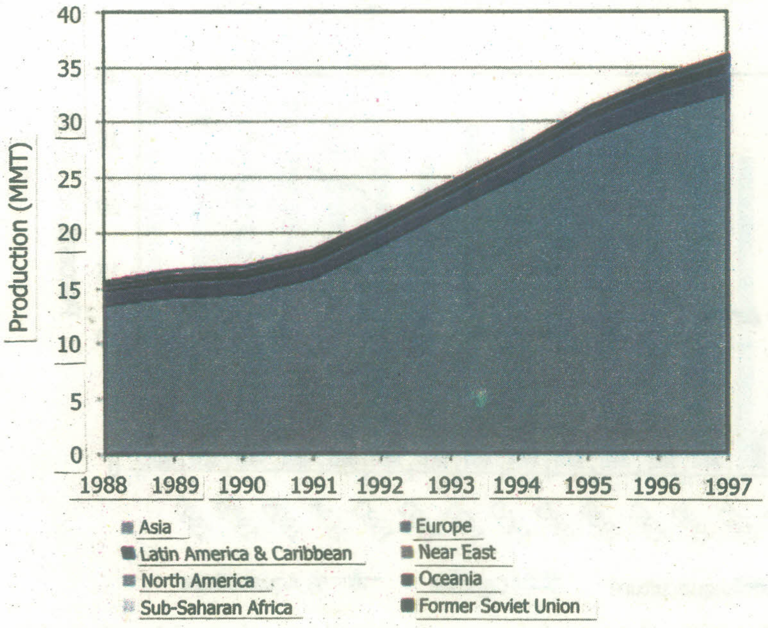

Fig. 3.4: Aquaculture production in the different continents/regions, 1988 – 1997. Source: www.fao.org

In spite of these generalized observations made for the sector, there is a marked disparity in aquaculture production between the different continents, regions and countries (Fig. 3.4).

Nonetheless, it has to be conceded that the initial upsurge in certain regions was, in all probability, linked to the cultural background, which in turn reflects a consumer preference for aquatic food products and a tradition of some form of fish culture.

Important changes have been seen with regard to the species cultured (Table 3.1). In 1988, ten species that were produced in highest quantity included five finfish, three aquatic plants and two molluscs. By 1997, five finfish, three mollusc and two aquatic plant species made up the top ten. Of these, the production exceeded 1 million mt in eight taxa (Table 3.1).

Table 3.1: The ten species that were produced in the highest quantity in 1988 and 1997, the amount produced is given in metric tones.

Species	1988		1997
Japanese kelp	2 072 383	Japanese kelp	4 401 931
Silver carp	1 587 691	Silver carp	3 227 617
Pacific cupped oyster	1 217 663	Pacific cupped oyster	2 974 460
Common carp	1 093 754	Grass carp(=White amur)	2 711 131
Bighead carp	725 603	Common carp	2 229 826
Laver (Nori)	670 816	Bighead carp	1 552 461
Grass carp(=White amur)	609 858	Japanese carpet shell	1 275 104
Wakame	492 196	Yesso scallop	1 256 799
Blue mussel	415 846	Crucian carp	862 554
Milkfish	345 829	Laver (Nori)	861 231

Source: www.fao.org

One of the most important facts of the sector is that in all continents, except Africa, there has been a significant increase in the production per caput over the period 1984 to 1997. The increase in production per caput in Europe was, however, comparatively smaller. It is within this context that the leading role of Asia in the global aquaculture sector has to be considered.

On the other hand, the sector has also witnessed the development of large-scale, industrial aquaculture during the last two decades, which is not so interlinked with the traditions mentioned previously, but may be due to the consumer preferences in the developed countries. The development of aquaculture for salmonids and shrimps in South America, salmonids in northern Europe, marine finfish in the Mediterranean Region and channel catfish in the United States are examples of this throughout the world.

In 1988, eight Asian countries/territories were among the top ten aquaculture producers, with China leading with a production of 7 million mt (Table 3.2). By 1997, the top ten was entirely composed of Asian nations, with China leading and providing 24 million mt. This means that its production had increased by 340 percent over the ten-year period. The Democratic People's Republic of Korea, Japan and Taiwan Province of China recorded reductions, while all the other Asian nations increased their production in this period, 13 of them recording at least a doubling in production. Also, by 1997, Thailand and Vietnam had emerged as major aquaculture nations.

Table: 3.2: The top ten aquaculture producing countries in 1988 and 1997. The amount produced is given in metric tones.

Country	1988		1997
China	6 995 409	China	24 030 313
Japan	1 425 991	India	1 862 250
Korea Dem. People's Rep	1 090 000	Japan	1 339 861
Korea Republic of	898 649	Korea Republic of	1 040 230
India	893 330	Philippines	957 546
Philippines	599 464	Indonesia	777 547
Indonesia	499 597	Thailand	552 356
United States of America	357 614	Bangladesh	512 738
Taiwan Province of China	300 981	Viet Nam	509 000
Spain	271 356	Korea Dem. People's Rep	489 321

Source: www.fao.org

SAQ 1

Discuss the main trends in aquatic products as food source during 1988 – 1997.

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3.2.2 Major Commodities of Aquaculture

Aquaculture is a very diverse activity, involving the culture of invertebrates to reptiles, being done in all types of aquatic environments.

Finfish

As indicated earlier, finfish is the major commodity that is cultured globally, where over 125 species are contributors, in all environments (fresh, brackish and marine waters) and temperatures (warm, temperate and cold). The number of species whose production exceeds 100 000 mt /yr is less than 20, of which 11 are cyprinids. The great bulk of finfish culture is constituted by freshwater species, followed by diadromous and marine species. Cyprinids and diadromous fish dominate freshwater culture, followed by carps and salmonids, in warm and cold climates, respectively. The global value of the produce of each category reflects the amounts produced.

Asia leads the world in finfish culture, producing nearly 90 percent of that produced globally in 1997 (Fig. 3.5). The dominance of Asia in finfish culture is further exemplified when one considers the proportion of each of the seven major groups of teleost fish cultured in each continent. From this analysis, it is evident that, with the exception of salmonid species, Asia leads in the culture of all the other groups.

Upon deeper analysis of the information provided in Fig. 3.5, notably on a regional basis, it becomes apparent that the culture of carnivorous finfish is a developed-country activity, while noncarnivorous finfish culture is essentially an activity made in developing countries.

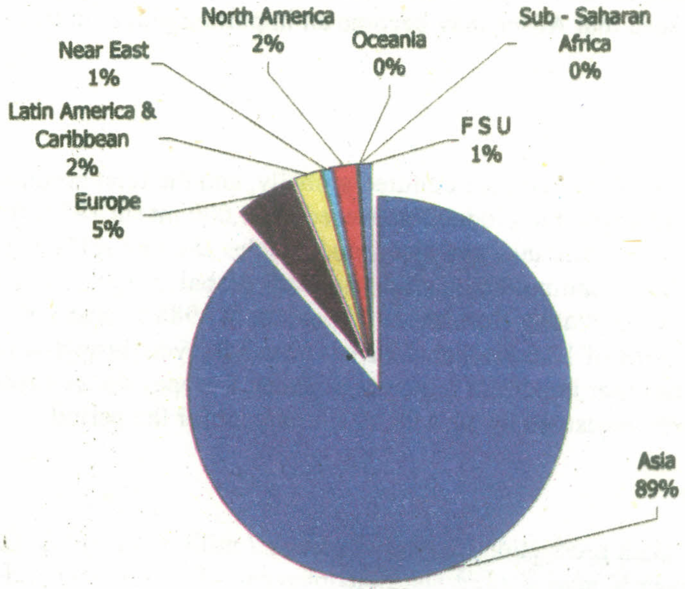

Fig. 3.5: Percent contribution to cultured finfish production by different continents.
Source: www.fao.org

Crustaceans

Compared to that reported for finfish production, the annual yield of cultured crustaceans is relatively small, currently measuring about 1.4 million mt. This is a sector that continued to grow, consistently and substantially, although few fluctuations observed during the process. A concurrent growth of crab culture, mainly a fattening process, has occurred, particularly in Asia, which has assisted the overall growth of crustacean aquaculture. All cultured crustaceans are relatively high valued, and the value of the different products is almost identical to the production.

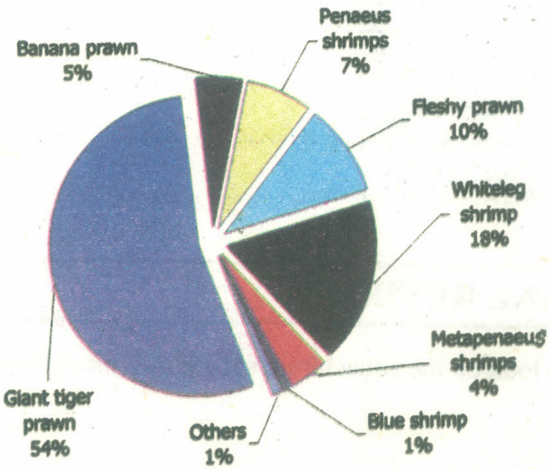

Fig. 3.6: The relative contribution of different shrimp species to the global cultured shrimp production.
Source: www.fao.org

Marine shrimp culture almost completely dominates crustacean culture, representing 96 percent that is done in brackish water and 73 percent of all crustacean aquaculture. The relative contribution of the various shrimp species to global cultured shrimp production is shown in Fig. 3.6, which shows that the tiger prawn, *Penaeus monodon*, contributes in excess of 50 percent to the total followed by the whiteleg shrimp, *P. vannamei* (18 percent), and the oriental or fleshy prawn, *P. chinensis* (10 percent).

Shrimp culture is essentially confined to Asia and South America and, interestingly, the production share of the latter has continued to increase steadily throughout the decade, rising from around 15 percent to nearly 20 percent of global production in 1997. It is envisaged that Africa may become an important player in this sector in the future.

Molluscs

Fifty-eight species of molluscs are cultured globally, and the total production is about 8.6 million mt. However, the production exceeded 50,000 mt (in 1997) for ten species only (two oysters, five mussels, two clams and cockles and one scallop species). As with the previous two commodities, Asia also leads global mollusc culture, its contribution growing steadily from about 76 percent in 1988 to nearly 90 percent in 1997, giving an APR of 12.6 percent. This has been achieved through a superior growth rate to the other important regional producer, Europe, whose expansion has been much slower, measured by an APR of 1.1 percent for the period.

Aquatic plants

Annual aquatic plant production currently exceeds 7 million mt and is confined to three marine seaweed taxa, the brown (Phaeophyceae - four species), red (Rhodophyceae - nine species) and green (Chlorophyceae - three species) seaweeds. The relative contribution of each of these groups to total production and the value of the produce, from 1984 to 1997, shows that the value of green seaweeds is slightly higher than that of the other two groups. Aquatic plant culture is almost totally confined to Asia, with recent culture activity expanding for Gracilaria in Chile, but elsewhere it is only of a very small scale (sub-Saharan Africa, Europe and Oceania).

SAQ 2

Explain the global trends in development of cultured crustaceans.

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3.3 REGIONAL REVIEW

We shall now take a look on the aquaculture scenario of the different regions of the world.

3.3.1 East Asia

The three most important fishing nations of the region including Japan, China and the Republic of Korea. The seas within this region include the north-west Pacific Ocean including the Sea of Japan, the East China Sea and the Yellow Sea. Fish production is an important economic activity particularly in coastal states of the region. The region is one of the largest fish producing areas of the world. Aquaculture production of the region contributes more than 70% of the global value. Fish consumption in the region is generally high, exceeding meat consumption in some of the countries. Annual average per capita fish consumption of the region amounts to 21 kg.

China, with its long history of aquaculture, is the world's largest producer of aquacrops. Carps and Tilapias are the most dominating species which are grown in pond-based integrated polyculture systems on the Yangtze River Delta and in the Pearl River Delta area. The area around ponds are often used for cultivating vegetable crops making use of the pond muck (farmyard manure) as fertilizers.

Aquaculture in Japan is restricted almost entirely to high value carnivorous marine species grown under intensive faming systems. The two major species are yellow tail and red sea-bream (bream is a salt water fish of the carp family). Marine plants constitute the second most important species under aquaculture followed by molluscs and crustaceans.

As a result of serious losses suffered by shrimp farms on account of disease out-breaks, environmental issues have become increasingly important considerations for future aquaculture development in the region.

3.3.2 South and South East Asia

The region includes countries from Pakistan in the West to Indonesia in the East. The region includes some of the most productive fishing waters in the world contributing about 27% in the global catch. Estimatedly, over 10 million people are employed in fisheries activities of the region. The average per capita consumption of fish in the region is 9 kg. Fish trade has expanded significantly in the region over the last decade and Thailand is the world's leading exporter of fish and fishery products.

Aquaculture production in the region has witnessed a spectacular increase in recent years. The region's contribution to world aquaculture production is to the tune of 17% by volume and 23% by value. In volume, the main producers of the region are India, the Philippines, Indonesia and Thailand. Finfishes are the chief constituents of the volume followed by crustaceans, marine plants and molluscs. Crustaceans contribute more than 50% of the total value of aquaculture produce.

Production of farmed finfish is mainly from freshwater pond aquaculture. Other species are cultivated in pens and cages (e.g. Tilapia) or in coastal ponds (e.g. milkfish).

Farmed shrimp culture has developed dramatically over the last decade contributing as much as 75% of total world production of cultured shrimp. The major shrimp producing countries of the region are Thailand and Indonesia. In several locations, rapid expansion of shrimp farming is said to have affected the coastal environment.

3.3.3 Near East and North Africa

No country in this region depends substantially on fish and fishery products as a mainstay of its economy. Average per capita consumption of fish in the region ranges from 40 kg in Yemen to 0.1 kg in Afganistan. The contribution of the region in global fish production is about 2%.

Six countries of the region, namely, Israel, Egypt, Saudi Arabia, Turkey, Cyprus and Iran, account for about 90% of the production consisting almost entirely of cultured common carp, Nile tilapia and silver carp. Molluscs and crustaceans make up the small balance.

Culture of marine fish is conducted mostly under intensive culture systems such as in near-shore cages and to a lesser extent in coastal raceways and lagoons. These systems depend totally on nutritionally complete aquafeed with high fishmeal and oil content.

3.3.4 Sub-Saharan Africa

Fisheries play an important role in many Sub-Saharan African countries as a major contributor to animal protein supplies, a foreign exchange earner and a generator of rural employment. The average per capita consumption of fish in the region is 7 kg per annum.

Unlike Asia, aquaculture is not a traditional practice in Sub-Saharan Africa. The region contributes merely 0.2% of total global production. Kenya, Madagascar, Nigeria, South Africa and Zambia are the major countries of aquaculture activities. The major species cultured in the region include tilapia, catfishes, carps, molluscs, and shrimps.

Freshwater fishes make up over 80% of the total aquaculture harvest and almost all Sub-Saharan African fish farming is carried out by subsistence rural operators in small freshwater ponds as a secondary activity to agriculture. Commercial shrimp farming is developing in some countries such as Medagascar, Mozambique, Guinea and Kenya.

3.3.5 North America

The region includes Canada, Greenland and the United states and the adjacent fishing areas of the north-west and central Atlantic and north-east Pacific. The per capita average fish consumption of the region is 22 and 23 kg (live weight equivalent) per annum and has been stable during the last few years.

Aquaculture in the region is a diversified activity which includes marine and freshwater fishes, crustaceans, molluscs and marine plants.

The emphasis in Canadian region is on coldwater species such as salmon, trout and molluscs. In United States, the main species under aquaculture include catfish, cupped oysters, tilapia, rainbow trout, golden shiner (used for bait), salmon, crawfish and shrimps. Catfishes, weight-wise, are grown more than all other species of aquatic organisms combined. The channel catfish is the most frequently farmed species with the blue catfish and the white catfish running a distant second and third. The center of the catfish farming is Mississipi.

The crawfish (=cray fish) is the most commonly cultured invertebrate and stands second only to catfishes in production. All the crawfish farms are located in the south-east, mostly in Louisiana.

Baitfishes (golden shiner) have long been a popular item for aquaculturists of United States. There are over 14,000 baitfish farms in the United states producing over $ 50 million worth of fish each year.

Tropical fish and invertebrate culture for aquarium hobbyist is also important. It is essentially a Florida-based operation.

Other important finfish species under aquaculture include salmon, large mouth bass, small mouth bass, pike and walleye. Frogs are grown for laboratory scientists as well as for food. Alligator is cultured in southern states both for meat and skin and are sold for high prices. Under current practices, the eggs are collected from the wild and hatched under controlled conditions. The young alligators are kept in shallow pools located in heated buildings where they grow and attain much greater size than wild ones.

The pond turtle, the red-eared slider (*Chrysemys scripta*) is cultivated for aquarium market.

Alligators and turtles are also reared with the objective to protect dwindling natural population.

3.3.6 Latin America and the Carribean

The region covers the South American continent, Central America and Mexico as well as the island states and territories of the Carribean. Important countries of the region include Brazil, Chile, Venezuela, Argentina, Cuba, Mexico. The region is note worthy in the sense that it was from this region on the world only where from scientists namely, Houssay, B.A., Cardoso, D.M. and Vote Ihring reported their first success in induced breeding of fishes by injection of fish pituitary extract which had revolutionized the aquaculture scenario of the world and fish production in the region accounts for 22% of the world total. The contribution of the fisheries sector in the economy of the region is highly concentrated in coastal and rural areas where it is the key and often the only source of employment and income generation. The per capita average fish consumption is about 9 kg per year. Latin American countries are major exporting countries of fish and fishery products and account for 11% of world exports with Chile as the main exporter. Shrimp and fish are the main items of exports.

Aquaculture production contributes about 2 and 5% of world production by volume and value, respectively. Aquaculture makes a similar contribution to total regional fisheries production, accounting for most of the production.

Shrimp culture in the region has increased very rapidly. Equador is one of the leading countries in the world in production of cultured penaeid shrimps. Salmon culture has also developed although almost exclusively in Chile. Aquaculture of freshwater fishes *viz.* tilapia, trout and carps and molluscs is also carried out. The herbivorous species "cachama" and "pacu" (*Colosoma* spp.) in Venezuela, Colombia and Brazil are considered to have a great potential in Latin America and elsewhere.

3.3.7 Europe

Fish production is important to many countries of the European region. The per capita average fish consumption varies from 30 kg per year in some of the Mediterranean and Nordic countries to 10 to 15 kg per year in some of the transition and island countries.

Nordic countries is a term used collectively five countries in northern Europe i.e., Finland, Iceland, Denmark, Norway and Sweden.

One of the most rapidly developing aquaculture activity of the region is that of Norway's salmon farming which has grown significantly since 1977. A large number of these salmon are exported to France and the United States. Currently, over 300 hatcheries in Norway sell trout and salmon fry for aquaculture. Salmon farming has now also spread to several other countries in the northern Europe, most notably is Scotland. In fact, aquaculture sector has undergone a revolution because of the success of salmon farming.

Trout, especially the rainbow trout, is also an important culture product by weight in Europe, constituting some 31% of all European aquaculture production.

Carps are the warmwater fishes of the region, especially in eastern Europe. They constitute 30% of European aquaculture.

Many finfishes in the region are grown for resource enhancement of open waters through ranching to support both commercial and recreational fisheries.

3.3.8 South Pacific

The region covers the western and central Pacific ocean, stretching from Australia in the west of Pitcairn Island in the east. Although the region contributes only about 2% of total world fishery production, however, it plays a critical role in the economy of the south Pacific states and territories. The region harbours one of the world's richest tuna fishing grounds, and fisheries exports from the region consist almost wholly of tuna. The average per capita consumption of fish in the region is 20 kg (live weight equivalent) per year.

The major contribution of aquaculture is through mussel culture in New Zealand. Other significant contribution is through the culture of salmon in New Zealand and of *Salmo salar* in Australia. Oysters and pearl oysters are other important species which are cultivated in the region.

Most of the aquaculture production of the region is derived from coastal aquaculture.

Table 3.3 showing region wise aquaculture production systems and practices is given below.

Table 3.3: Aquaculture production systems and practices, by region.

Region	Major Culture Species	Major Culture Systems	Major Culture Practices	Scope for Future Development Needs for Further Expansion
ASIA	At least 75 species; diverse freshwater and marine species, including high-value shrimps, molluscs, seaweeds, with carps and seaweeds dominating production	Traditional extensive to intensive	- Fish ponds - Fish pens and fish cages - Floating rafts, lines, and stakes for molluscs and seaweeds	Development of culture-based fisheries in inland lakes, river, floodplants, and permanent and temporary reservoirs and barrages Resource enhancement programme integrated with environmental management
PACIFIC	Mussels and oysters, red seaweeds	Intensive/semi-intensive to extensive	- Hanging lines for mussels and pearl oysters - Offshore cages for salmon - Pond culture for shrimps, tilapia, catfish, milkfish - Freshwater pens for crayfish	Production of high-value species for select markets; Small-scale aquaculture for local markets; Improved management of fishery resources, particularly reef fisheries

LATIN AMERICA	50 species of fish, crustaceans, and molluscs, including freshwater fish and marine shrimp in South America and molluscs in Central America	Extensive to semi-intensive and intensive	- Offshore cage farming of pacific and Atlantic salmon - Ocean ranching in Southern Ocean - Semi-intensive farming of marine shrimp in coastal ponds and extensive farming of freshwater fish in ponds	Production of species for export and marine shrimp and salmon
AFRICA	>26 freshwater fish; the most important being tilapia and common carp, molluscs and oysters also	Mainly extensive rural-based, integrated with poultry and animal husbandry, rice-fish farming; some intensive in raceways and floating cages	- Fish pond culture for freshwater fish - Raceways and floating cages for marine species	Increased emphasis on higher value catfishes for urban markets on marine species of fish and crustaceans for select national market and export Culture-based fisheries in lakes and reservoirs Development of coastal lagoons which are almost totally unexploited
MEDITERR-ANEAN	>50 individual species, mostly freshwater and brackishwater fishes – most important being salmonids and carps; oysters and mussels	Well-diversified modern practices, with highly technical and intensive systems in developing countries and semi-intensive and extensive elsewhere	- Fish pond - Fish cages - Ocean ranching	Production of high-value species of tourism and export Integrated coastal zone management

CARIBBEAN	About 16 species of tilapias, carps, marine shrimp and freshwater prawns, oysters and seaweeds		- Floating cages in reservoirs - Fish pond farming in freshwater - Culture-based fisheries in reservoirs - Rope production of mollusks	Priority is for aquaculture production for local markets

Source: ADCP Aquaculture Regional Profiles, 1986b

SAQ 3

Fill up the blanks:

i) .... enjoys an obvious dominance as an aquaculture producer in the world.
ii) Aquaculture activities in China are dominated by ....
iii) Aquaculture in Philippines and Indonesia is dominated by ....
iv) The per capita consumption of fish in .... is the lowest in the world.
v) Aquaculture sector in Europe has been revolutionized due to success achieved in .... farming.

SAQ 4

State whether following statements are true or false.

i) No countries in Sub-Saharan Africa depend substantially on fish and fishery products.
ii) Aquaculture of bait fishes is the most popular in South Pacific region of the globe.
iii) Crustaceans do not contribute substantially in global aquaculture production by weight but by value, indeed, they do.
iv) Brackishwater sector maintains its dominance in global aquaculture production.
v) Aquaculture is one of the fastest growing food production activities in the world.

3.4 SUMMARY

You have learnt in this unit that:

- The rapid growth of aquaculture over the past decades kept the global volume of fish production expanding despite the leveling of marine catches.
- Aquaculture is one of the fastest growing food production activities in the world.
- The share of cultured aquatic commodities from Asia accounts for about 80% of the world aquaculture production.
- Although cultured finfish and shellfish contribute significantly to total fishery production, aquaculture in most countries is dominated by a few species such as carps in China and India, oysters and mussels in Japan, Korea and France and milkfish in Philippines and Indonesia.
- Freshwater finfish production maintains its dominance both by weight and volume in global aquaculture production.

- Although crustaceans contribute only 4% of global aquaculture production by weight but value-wise they contribute 18% of the total value.
- No countries of Near East and North Africa depend substantially on fish and fishery products.
- The per capita average fish consumption in Afganistan is the lowest (0.1 kg per annum) in the world.
- The South Pacific region harbours one of the richest tuna fishing grounds in the world.
- Aquaculture sector in Europe has been revolutionized due to success achieved in salmon farming.
- Next to catfishes, aquaculture of baitfishes is very popular in the United States. There are over 14,000 baitfish farms in the country producing over $ 50 million worth of fish each year.
- High concentrations of intensive fish and shrimp culture systems led to environmental problems at several locations in the world and put a question mark on the sustainability of aquaculture development.
- As production from capture fisheries resources has apparently reached its limits in many countries, aquaculture is expected to produce the extra volume of fish production required by the expanding world population.

3.5 TERMINAL QUESTIONS

1) Discuss an overall scenario for the present status of global aquaculture with respect to finfish, molluscs, and aquatic plants.

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2) Write short notes on aquacultural activities of the following regions of the world.

i) South Pacific

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ii) Sub-Saharan Africa

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3.6 ANSWERS

Self-assessment Questions

1. Ref. Sec. 3.2.
2. Ref. Sec. 3.2.
3. i) Asia, ii) Carps, iii) Milkfish, iv) Afganistan, v) Salmon
4. i) F, ii) F, iii) T, iv) F, v) T

Terminal Questions

1. Ref. Sec. 3.2.
2. i) **South Pacific:** Although the region contributes only about 2% of total world fishery production. The fishery sector, together with tourism plays a critical role in the economy of the South Pacific states and territories. The average per capita consumption of fish in the region is 20 kg per year. Most of the aquaculture production of the region is derived from coastal aquaculture.

   ii) **Sub-Saharan Africa:** The average per capita consumption of fish is 7 kg per annum. Aquaculture is not a traditional practice here. The region contributes merely 0.2% of total global production. Freshwater fishes make up over 80% of the total aquaculture harvest. Commercial step farming is developing in some countries such as Medagascar, Guinea and Kenya.

UNIT 4 GENERAL CONSIDERATIONS FOR AQUACULTURE

Structure

4.1 Introduction
  Objectives
4.2 Considerations for Aquaculture Development
  Developmental Goals
  Choice of Species
  Technology Availability
  Availability of Inputs and Support Facilities
  Financial Requirements
  Environmental Considerations
  Legal Aspects
4.3 Constraining Factors for Aquaculture Development
  Possibilities of Disease Outbreak
  Intensification of Land Use and Scarcity of Water
  Short Supply of Feed Ingredients
  Social and Economic Constraints
4.4 Summary
4.5 Terminal Questions
4.6 Answers

4.1 INTRODUCTION

Aquaculture is looked upon as an excellent source of animal protein, a potential source of employment, revenue generation and also as an instrument to utilize land and water resources more effectively. The prospects for aquaculture, however, vary in different parts of the world depending upon physical environments, markets, socio-economic conditions and so on.

The selection of an aquaculture system for a particular situation depends on several factors. We shall discuss these factors at length in this unit.

Objectives

After studying the unit you will be able to:

- identify the factors which govern aquaculture development,
- describe the site-specificity of various aquaculture technologies and its varied approaches for adoption,
- explain about the constraining factors of aquaculture development,
- highlight the importance of environmental considerations in the context of present day aquaculture.

4.2 CONSIDERATIONS FOR AQUACULTURE DEVELOPMENT

Development of an aquaculture system depends on many factors. Broadly these factors can be classified as availability of technology, choice of species, fund availability, input and support facility (Fig. 4.1).

Objectives of Aquaculture Development
- Local consumption
- Employment and income generation
- Foreign exchange earning
- Socio-economic upliftment
- Resource enhancement of open water
- Fun and Fancy

Technology availability
- Level of its complexity
- Transferability of the technology to target beneficiaries
- Fine tuning of technology for local application
- Facilities for water replacement,
- Treatment facilities for wastewater discharged from the farm

Socio-economic, legal and environmental aspects
- Social and cultural tradition
- Environmental impacts
- Permission for doing aquaculture
- Profitability
- Risk security due to crop failure, looting etc.

AQUACULTURE DEVELOPMENT

Choice of species
- Acceptability to consumers
- Adaptability to local condition for profitable aquaculture
- Good market potential

Input and support facility
- Water supply
- Seed
- Feed
- Fertilizer
- Processing plants
- Ice plants
- Cold storage
- Manpower
- Training input

Fund availability
- Facilities for preparing bankable projects
- Loan availabilities
- Subsidies
- Funding organisations

Fig. 4.1: Factors which govern aquaculture development.

4.2.1 Developmental Goals

The primary consideration in the choice of an appropriate aquaculture system for a particular situation is to see that what are the underlying goals/objectives of the proposed project and the beneficiaries it envisages to assist. The developmental goals can include any or all or a combination of the following:

i) Production of fish/prawn etc. for local consumption
ii) Employment and income generation
iii) Greater foreign exchange revenues
iv) Socio-economic upliftment
v) Resource enhancement of open waters
vi) Fun and fancy

Depending on the developmental goals and target beneficiaries, the approach to aquaculture development could be small-scale, low-input and low technology or large-scale, high input, and high technology.

Aquaculture development, when pursued by the private sector on a commercial scale, is usually undertaken primarily for financial profit. In contrast, government led and implemented aquaculture projects may be motivated principally by socio-economic goals like the provision of alternative employment and livelihood opportunities for municipal / artisanal fishermen, or the generation of greater foreign exchange earnings for the country.

Depending on the specific project goals and the target beneficiaries, the approach to aquaculture development may be small-scale, low-input and low technology or large-scale, high investment and high technology, as the case may be. If the project is envisioned to help coastal subsistence fisherman improve their sound-economic condition, the approach to be taken must necessarily involve small-scale farming which requires low capital outlay, low technology and low risk, as in seaweed farming, mollusc culture or tilapia cage culture. On the other hand, commercial aquaculture operations can be as large-scale, high-input, and high-risk as the owners can afford, as in highly intensive shrimpfish ponds or large-scale fish pen operations.

4.2.2 Choice of Species

The choice of culture species is more closely linked with the objectives of the development as such a strategy needs to be developed to achieve the set goals. Not all fishes/prawns or shrimps are suitable for aquaculture. Some species are more appropriate for commercial aquaculture such as high value shrimps while some species are suited for culture in specific types of enclosures viz. pens and cages. Certain species, on the other hand, are more acceptable in certain countries than in other and so on.

The choice of species for culture depends on a number of factors. The aquacultural traits of species are attributed to several considerations such as follows:

i) **It must withstand the climate of the region in which it will be raised:** The rearing of cold water fish like salmon and trout is limited to temperate regions or mountain areas of tropical countries because they cannot tolerate warm water with its low oxygen content.

ii) **Its rate of growth must be sufficiently high:** Small species, even if they reproduce well in ponds and accept formulated diets, are not the most suitable for rearing. Also the best culture species are those which are low in the food chain e.g. plankton feeders, herbivores and detrivores. Their culture is also least expensive, even on an intensive scale, because they do not need to be given diets having a high content of animal protein.

iii) **It must be able to reproduce successfully under culture conditions:** Species for culture should be able to reproduce in captivity/confinement without needing special conditions that have to be fulfilled, and which give high returns on eggs and fry. Although it is possible to rear species whose reproduction in confinement is not possible at all (e.g., some carps) or whose reproduction under hatchery conditions has not yet been possible on a commercial scale. (e.g. milkfish in the Philippines), the sustainability of the grow out operations is hampered by the seasonal unavailability of wild fry for stocking in fish pens and/or fish ponds.

iv) **It must accept and thrive on abundant and cheap artificial food:** Culture species which feed on cheap artificial feeds and give low feed conversion ratios (FCRs) also tend to give very good production rates, thus bringing in better financial returns.

v) **It must be acceptable to the consumers:** Even if all the foregoing criteria are met by a candidate species, it is not worth culturing if there is no market for it. It is possible, to promote the acceptability or consumption of a particular species to ensure that it will eventually sell in the market.

vi) **It should support a high population density in ponds:** Social and gregarious species which can grow well to marketable size even under high density condition in ponds or tanks (e.g. tilapia) are preferable to those which can be grown together in dense number only up to a certain age beyond which they tend to eat each other (e.g. pike).

vii) **It must be disease - resistant :** Reared fish must be resistant to disease and accept handling and transport without much difficulty. Tilapia is an ideal species for culture because of its high resistance to disease even in highly intensive culture systems.

Often a species is selected for introduction into a new area. This is done only when the selected species is adjudged that:

- it would fulfill the requirement of having such a species, the kind of which is not existent in the area of transplantation
- the species would not compete with valuable native species to the extent of contributing to their decline
- the species would not cross with native species and produce undesirable hybrids
- the species would live and reproduce in equilibrium with its new environment
- the species would not bring any pest and disease in the areas of introduction.

4.2.3 Technology Availability

The selection of a particular aquaculture system necessarily depends on whether or not such technology is available in the project area and if so, what is the level of its complexity and/or transferability to the target beneficiaries. As problems of aquaculture are very often site-specific, even well established technologies have to be adapted, modified or fine tuned for local application and tested to determine their economic viability.

In general, simple, low-cost and low technology systems (such as tilapia culture) are easier to transfer to the end users and have greater chances of success as compared to more sophisticated and relatively high cost technology system like those involved in shrimp farming, especially using intensive culture techniques.

There exists a good number of options for treating a species for aquaculture. For example, carps, which constitute the most popularly farmed species world over, are cultured on mono and polyculture basic through various approaches viz. fertilizer and feed-based system, wastewater-based system, bio-fertilizer-based system, integrated aquaculture-based system and so on.

If aquaculture is being considered as an alternative livelihood for displaced coastal fishing families, the preferred system is one that will enquire to use of simple techniques and low-cost production facilities whose construction and operation may involve entire families or communities e.g. sea weed and mollusc farming. On the other hand more complex technologies which require higher capital and other inputs and which promise better profits are adopted by medium to large scale entrepreneurs who have the capability to engage the services of technical specialists in running their operations.

Dissolved Oxygen (DO)

The amount of oxygen dissolved in water or sewage. Concentration of less than 5 ppm can limit aquatic life or cause offensive odors. Low DO is generally due to excessive organic matter present in water as a result of inadequate waste treatment and runoff from agricultural or urban land.

4.2.4 Availability of Inputs and Support Facilities

The most important input requirement is the availability of good quality water (D0 5 to 9 mg/l). If water is available in plentiful amount, one may decide to go in for running water aquaculture and when in limited quantity, aquaculture system with recirculating water will have to be selected.

Matching with the level of the selected aquaculture technology, the availability of critical production inputs is also necessary. This includes seed, feed, fertilizers, processing plants, ice plants, cold storage facilities etc. Equally important is to ascertain adequate availability of manpower, technical assistance including training and extension support is in the area for helping the aqua farmers in technology adoption.

For large-scale intensive, commercial operations, especially those geared for the export market, the constant availability of seed and feed is critical as well as the existence of adequate post-harvest handling.

4.2.5 Financial Requirements

The financial requirement of aquaculture projects increases as a function of technology level and degree of complexity of the culture system, with extensive systems requiring the least capital investment and intensive systems requiring the most.

It is to be borne in mind that where investment costs are high and land and labour are limited and costly, the choice will naturally be for intensive aquaculture in order to achieve maximum yield per unit area. On the other hand, where land, labour and fish/prawns are inexpensive and feed is unavailable and costly, the choice will fall for extensive culture utilizing large pond areas and natural food.

4.2.6 Environmental Considerations

Of late, there is a growing concern over the possible adverse impacts of aquaculture activities on the environment, especially as a result of intensive aquaculture operations. This is mostly on account of disease outbreaks due to water quality problems, widespread destruction of mangroves, eutrophication of natural waters from high nutrient loads discharged from aquafarms, public health risks and so on. It is therefore, important to take environmental considerations into account while selecting a culture system for adoption, either by reducing the extent to which aquaculture practices interfere with the ecology of the aquatic environment or by making the environment itself more amendable to the aquaculture pursuit.

Concern that coastal aquaculture can have adverse impacts on the coastal environment has prompted expert in this field to suggest practical guidelines for siting and operating aquaculture installation in mangrove systems. Some of these can be summarized as follows:

- Establishment of types of aquaculture which do not involve destruction of mangroves and associated flora and fauna e.g. fish cages and fish pens in open water areas.
- Integrated aquaculture and forestry e.g. planting of mangroves along fish pond dikes and other nearby suitable areas.
- Preservation of a functional ecosystem by means of:
  - establishment of aquaculture in areas already reclaimed from mangroves rather than on productive mangrove stands,
  - utilization of the least productive parts of the mangrove forest or those with the lowest value trees,
  - locating aquaculture sites towards the landward side of the mangroves to preserve the productivity of the most productive portions for capture fishery resources,
- Paying ample attention to site selection, culture installation design and the management of culture operations.

The possible environmental impacts of culture systems are listed in Table 4.1.

Table 4.1: Possible environmental impacts of aquaculture.

Culture System	Environmental Impact
EXTENSIVE	
1. Seaweed culture	May occupy formerly pristine reefs; rough weather losses; market competition; conflicts/failures, social disruption

2.	Coastal bivalve culture (mussels, oysters, clams, cockles)	Public health risks and consumer resistance, microbial diseases, red tides, industrial pollution; rough weather losses; seed shortages; market competition especially for export produce; failures, social disruption.
3.	Coastal fishponds (mullets, milkfish, shrimps, tilapias)	Destruction of ecosystems, especially mangroves; increasingly non-competitive with more intensive systems; nonsustainable with high population growth; conflicts/failures, social disruption.
4.	Pen and cage culture in eutrophic waters and/or rich benthos (carps, catfish, milkfish, tilapias)	Exclusion of traditional fishermen; navigational hazards; conflicts, social disruption; management difficulties; wood consumption.
SEMI-INTENSIVE		
1.	Fresh and brackishwater pond (shrimps and prawns, carps, catfish, milkfish, mullets, tilapias)	Freshwater; health risks to farm workers from waterborne diseases. Brackishwater; salinization/acidification of soils/aquifers. Both: market competition, especially for export produce; feed and fertilizer availability/prices; conflicts/failures, social disruption.
2.	Integrated agriculture-aquaculture (rice-fish; livestock/poultry-fish; vegetables –fish and all combinations of these)	As freshwater above, plus possible consumer resistance to excreta-fed produce; competition from other users of inputs such as livestock excreta and cereal brans; toxic substances in livestock feeds (e.g., heavy metals) may accumulate in pond sediments and fish; pesticides may accumulate in fish.
3.	Sewage-fish culture (waste treatment ponds; latrine wastes and used as pond inputs; fish cages in wastewater channels)	Possible health risks to farm workers, fish processors and consumers; consumer resistance to produce.
4.	Cage and pen culture, especially in eutrophic water or on rich benthos (carps, catfish, milkfish, tilapias)	As extensive cage and pen systems above.
INTENSIVE		
1.	Freshwater, brackishwater and marine ponds (shrimps; fish, especially carnivores – catfish, snakeheads, groupers, sea bass, etc.)	Effluents/drainage high in biological oxygen demand (BOD) and suspended solids; market competition, especially for export product; conflicts/failure, social disruption
2.	Freshwater, brackishwater and marine cage and pen culture (finfish, especially carnivores – groupers, sea bass, etc. – but also some omnivores such as common carp)	Accumulation of anoxic sediments below cages due to fecal and waste feed build-up; market competition, especially for export produce; conflicts/failures, social disruption; consumption of wood and other materials.
3.	Other – raceways, silos, tanks, etc.	Effluents/drainage high in BOD and suspended solids; many location-specific problems.

4.2.7 Legal Aspects

The legal aspects of aquaculture are sometimes complicated. Many acts and ordinances have been introduced such as coastal regulatory zone (CRZ), wild life protection act etc. An especially vexing problem is encountered in locating aquaculture ventures in areas where there are several different users of the same site, such as lakes, reservoirs and coastal areas which are used for recreation, harbour, shipping industry, military purposes and so on. Established legislations often favour such interests over those of aquaculture. This necessitates looking into all such pros and cons while taking up any aquaculture project.

Coastal zone is the zone of interaction between the land and the marine environment. The land and sea boundaries of the coastal zone vary widely from one location to another. On land, it encompasses the sector containing the majority of shore line uses that have a direct influence on coastal habitats and resources. The coastal zone should be limited to area where majority of uses occur like aquaculture, coastal navigation.

4.3 CONSTRAINING FACTORS FOR AQUACULTURE DEVELOPMENT

It is true that aquaculture holds immense potential for meeting our future requirements of proteinous food, but it is also besit with several constraining factors. These constraining factors are also given adequate weightage while planning for an aquaculture project.

4.3.1 Possibilities of Disease Outbreak

Like all other animals, finfish and shellfish species raised under semi-intensive and intensive aquaculture systems are highly prone to stress due to high density stocking, rough handling and inappropriate water quality management. They are thus highly susceptible to outbreak of disease and mass mortalities.

4.3.2 Intensification of Land Use and Scarcity of Water

The expanding world population has already started weighing heavy on the availability of land for agriculture. Much of the current stagnation in agriculture production has been traced to population pressure and land degradation which are undermining agriculture's current condition and future prospects.

The lands available for aquaculture are perhaps more limited than previously supposed. The situation obviously denotes that aquaculture is going to have to compete with the many other uses to which land, water and nutrient resources can be put, and as population pressure mounts it is to be expected that priority will be given to cereal crops and vegetable protein sources.

Particular competition will come between irrigation and aquaculture for use of water. Availability of clean water is fast becoming one of the major limiting factors for life. Sooner or later, the onslaught is also going to fall on aquaculture too.

4.3.3 Short Supply of Feed Ingredients

Aquaculture pursuits fall under two broad categories, one is culture of high value carnivorous fishes and shrimp and another is culture of lower value species. While aquaculture of former is based on supplies of fish meal and trash fish as aqua feed inputs, aquaculture of the low value species is largely based on locally available vegetable wastes.

Fish meal and trash fish have already become commodities of scarce availability and in due course of time, it is definitely going to tell upon the progress of aquaculture of high value aquatic organisms. Foods for the low food chain species, on the contrary, are more abundant. It, thus, implies that the best potential for future advances in aquaculture should be obtained using lower food chain species such as carps and tilapias.

4.3.4 Social and Economic Constraints

Experience has shown that social and economic constraints are among the most serious constraining factors to the goal of diversifying rural agricultural options by introducing aquaculture into areas where potential is good but practice is so far lacking. The problems specially arise on account of:

- overcoming traditional land leasing patterns
- finding time for a new activity in already busy schedules
- influencing perceptions of risk and food security
- allocation of scarce financial resources for aquaculture
- serious lack of knowledge and experience due to lack of training

SAQ 1

Fill up the blanks

i) Where investment costs are high and land and labour are limited .... aquaculture is the best choice.
ii) Tilapia culture is a .... cost technology.
iii) Extensive systems of aquaculture utilize .... pond areas.
iv) Financial requirement of aquaculture projects increases as a function of .... level.
v) The approach to aquaculture development is decided on the basis of .... and ....

SAQ 2

State whether following statements are true or false

i) Prospects of aquaculture vary in different parts of the world.
ii) All aquatic organisms can be cultured under controlled conditions.
iii) Aquatic organisms also suffer on account of stress.
iv) The availability of land for aquaculture are more limited than previously supposed.
v) Finding time for aquaculture in already busy schedules of rural people is a common social constraint.

4.4 SUMMARY

In this unit, you have learnt that:

- Selection of an aquaculture system for a particular situation rests on several considerations.
- The approach to aquaculture development is decided on the basis of the developmental goals and target beneficiaries of the project.
- All aquatic organisms are not suitable for aquaculture.
- Introduction of a species into a new area is done following the prescribed guidelines for the same.
- In general, low-cost, low technology systems are easier to transfer to the end users compared to high cost technology.
- Financial requirement of aquaculture projects increases as a function of technology level and degree of complexity of the culture system.
- Besides availability of technology, equally important is to ascertain the availability of inputs and support facility for the envisaged aquaculture projects.
- Intensive aquaculture is the best option for such areas where investment costs are high and land and labour are limited and costly.

- An especially vexing problem is encountered in locating aquaculture ventures in areas where there are several different users of the same site.
- With the availability of hi-tech aquaculture systems, it has become necessary, particularly for large aquaculture projects, to look into its possible negative impacts on environment before implementation.

4.5 TERMINAL QUESTIONS

1. Enumerate the factors which govern the choice of species for aquaculture.

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2. What are the adverse impacts of aquaculture on the environment?

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3. What are the important constraining factors for aquaculture development?

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4.6 ANSWERS

Self-assessment Questions

1. i) intensive
   ii) low
   iii) large
   iv) technology
   v) developmental goals and target beneficiaries
2. i) T ii) F iii) T iv) T v) T

Terminal Questions

1) The species must
   a) have good market potential
   b) withstand the climate of the region
   c) be disease resistant
   d) be able to reproduce successfully

2) This is mostly on account of disease outbreaks due to water quality problem, eutrophication of natural water and widespread destruction of mangroves.

3) The constraining factors for the aquaculture development are:

- Intensification of land use
- Scarcity of water
- Short supply of feed ingredients
- Possibilities of disease outbreak
- Social and economic constraints

UNIT 5 PROSPECTS OF AQUACULTURE FOR FUTURE DEVELOPMENT

Structure

5.1 Introduction
  Objectives
5.2 Challenges in Aquaculture
  Technical Challenges
  Role of Government
  Inter-regional Cooperation
  Culture Based Fisheries
  Education, Training and Extension
  Marketing Issues
5.3 Future Development
  Shift from Extensive to Semi-intensive and Intensive Systems
  Ranching of Open Waters
  Awakening towards Environment Protection
  Greater Stress on Sewage-fed Aquaculture
  New Candidate Species for Aquaculture
  Resorting to Effective Mechanisms for Transfer of Technology
5.4 Summary
5.5 Terminal Questions
5.6 Answers

5.1 INTRODUCTION

Aquaculture is a budding enterprise in most parts of the world. It is growing very rapidly in many countries of the world and is maintaining its position as one of the faster growing food production activities in the fray. In sharp contrast with the 10,000 year old history of traditional agriculture, much of the aquaculture activities have developed only during past 3 to 4 decades. There is a serious lack of entreprenual knowledge and experience in aquaculture. The lack of training at all levels is obvious. In some areas, there are also legal, political and environmental opposition to aquaculture development. Even in areas where sufficient knowledge and support services are available to facilitate development of profitable aquacultural pursuits, competition for land and water often becomes constraining factor.

Despite these negative reflections, however, the future prospects for aquaculture are indeed very good.

Objectives

After studying this Unit, you should be able to:

- explain about negative reflections of aquaculture which are to be looked into,
- describe the aspects which are to be emphasized for future development of aquaculture,
- discuss the right approach for encasting the full potentials of aquaculture, and
- explain the importance of training input in aquaculture.

5.2 CHALLENGES IN AQUACULTURE

Each and every forecast made for aquaculture in the new millennium provides a major challenge, while offering, at the same time, a host of opportunities, although these will differ, to a greater or lesser extent, between nations, regions and continents. There is a clear call for the development of suitable strategies, be they national, regional or inter-regional, where the sharing of information is commonly highlighted. To be concise, the global strategies may be two-fold:

- to increase aquaculture production significantly, so that it continues to have an impact on food security, employment generation and social equity; and
- for all development to be sustainable and environmentally sound.

In order to achieve these primary objectives without compromising any of the basic goals of aquaculture, there are common challenges cum strategies that the sector will have to face. The major ones are the following:

5.2.1 Technical Challenges

The individual technical challenges, and the research and development needs of the sector, are treated under separate themes within this unit.

Foremost amongst these are:

- genetic improvement of major aquatic species used in aquaculture;
- feed developments, encompassing both a decreasing dependence on fish meal as a major protein source in feeds and a lowering of nitrogen and phosphorous in effluent; and
- improvements in the health management of cultured organisms.

The genetic improvement of cultured aquatic organisms has lagged behind considerably other food production sectors (i.e. plant crops and animal husbandry). Amongst the species reared, some improvement in performance has been achieved through genetic selection in only two fish groups, namely salmonids and tilapias.

5.2.2 Role of Government

The role of government will undoubtedly be the most variable element in the aquaculture development. The suggested roles for government range from zero involvement to complete control of aquaculture development. In the early years of this millennium, national governments will have to make crucial decisions concerning the sector, particularly in regard to its role in extension services and active participation in regional and inter-regional institutions. Governments will also need to establish suitable policies to facilitate and augment aquaculture development and, most of all, remain alert to the establishment of fair legislation and not be subject to the dictates of various lobbyists. Governments need to accept that regulatory frameworks have to be fair whilst being responsible and responsive to identifiable problems and constraints.

The governmental role has to go beyond mere "policing" of the sector's activities and be developed, so that it encompasses working hand-in-hand with practitioners. To be more effective than in the past, government should make investments in partnerships, where appropriate and needed, in order to solve common problems.

5.2.3 Inter-regional Cooperation

It is often conceded that the Asian dominance in global aquaculture is partly a result of effective cooperation amongst the nations of this region, especially in facilitating the transfer, adoption and extension of technology. A significant part of this is due to the institutional frameworks that were established over 20 years ago and have become increasingly effective, leading the nations through the path of sustainable development.

It is important, and indeed crucial, that governments give sufficient recognition to the sector. It is a fact that the sector has almost always played second fiddle to agriculture and fisheries, for instance. While recognizing that, in most countries, agriculture contributes more than aquaculture to the Gross Domestic Production (GDP), it is timely that governments recognize both the contribution and the development potential of the sector, providing the recognition it deserves in national planning and policy development.

5.2.4 Culture-based Fisheries

As pointed out previously, the availability of resources (land and good quality water) for expansion of the area allocated to aquaculture is likely to be small. Consequently, the majority of the production increases foreseen will have to be obtained through increased productivity. Culture-based fisheries are attractive to most environmental groups, as the activity entails little to no manipulation of the environment. A good example of the effectiveness of culture-based fisheries is increasing fish production is China.

Many nations are now examining the possibilities of using inland lakes and reservoirs to improve and/or start culture-based fisheries. Indeed, this subject is seen as a major means of enhancing fish production, and it is estimated that this form of aquaculture is one of the fastest expanding sectors of fisheries. The aims will differ between nations and regions since, in the developed world, sport fishing will be the main result while, in developing countries, culture–based fisheries provide an easy access to a source of animal protein.

Culture-based fisheries, however, will continue to use exotic species where appropriate (e.g. where the exotic species already exists or where environmental impacts have been minimal). Exotic species have often proven to be the ones that give the most effective and profitable yields. In general, most successful stocking and enhancement programmes involve both introduced and native species.

5.2.5 Education, Training and Extension

The education and training needs of global aquaculture, as well as, the extension requirements, will be different within the regions, following the degrees of sectoral development. For example, in Asia, training and education is fairly satisfactory at the farmer level, this being an ongoing activity facilitated by regional bodies. In most regions, extension workers have a very strong commodity and/or discipline-oriented background. In view of the envisaged aim, that aquaculture should move rapidly towards sustainable development, a more holistic approach would need to be superimposed over the classic methodology. Regional institutions are likely to play an increasingly important role in providing guidance at the national level in this regard.

Certain regions are perhaps ready for the next step forward, which can only be achieved through technological advances and development. In Asia, on the other hand, a contrasting situation is to be seen. While there is already a large amount of knowledge available on small-scale/rural aquaculture, the dissemination of this knowledge to practitioners is, unfortunately, less effective than desired. On the other hand, Asia will also need to prepare for the next technological leap, which calls for a rationalization of its education programmes and the acquisition of critical mass of researchers.

In view of the rapid developments concerning communication using information technology, the sector will have to be increasingly innovative in the methods of the dissemination of knowledge.

5.2.6 Marketing Issues

Marketing issues are common to both rural and industrial aquaculture, but the manner of their handling may be different. These are issues that are common to the sector in both developed and developing countries.

It is not uncommon for sectoral analysts to refer to aquaculture products as being high- and low-valued commodities. In the past five to ten years, some notable changes have occurred within the national and international markets for aquaculture products, where the specific examples of Atlantic salmon, European seabass and tilapia can be cited. These changes are not only in respect of prices, but also the market destinations. The prices of Atlantic salmon and European seabass have diminished considerably (-53 percent in both cases).

On the other hand, tilapia, once mooted as the "aquatic chicken" of the 1980s and the "poor man's fish" (Smith & Pullin, 1984), has established a position within the supermarkets in developed countries. The success of tilapia is, without doubt, linked to the provision of fillets at a reasonable price, giving consumer satisfaction.

Where aquaculture production has increased, but is not associated with concurrent market development, market crashes can occur.

SAQ 1

In your opinion, what is the most important challenge in development of aquaculture and why?

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5.3 FUTURE DEVELOPMENT

In the new millennium, it is expected that the basic paradigm change will be from that of increasing production at almost any cost to that of attaining a sustainable increase in production with minimal environmental disturbance. With these paradigm changes, aquaculture will increase its contribution to food security, poverty alleviation and social equity.

The most significant driving force for aquaculture development in coming decades will be the rapidly expanding world population leading to the increasing demand of aquacrops. In a country like India, owing to accentuating modernity, religion will hardly be able to hold its restrictions on feeding habits of the people. Nutritional awareness, particularly the switch over from red to white meat, coupled with rising per capita income in the coming decades will cause appreciable upsurge in fish eating population of the country. The situation will, naturally, compel mobilization of al the available channels of food production. The growing mass awareness towards potentials of aquaculture will make everybody realise that aquaculture has advantage over other farming systems (agriculture and livestock raising) in being more efficient with regard to land, feed and energy utilization and also that the production potential of aquaculture as the cheapest source of animal protein is second to none.

In order to realise the potentials of aquaculture in greater measure during the coming decades, desired efforts would ensure. Major emphasis of future development will be on the following issues:

5.3.1 Shift from Extensive to Semi Intensive System

Land, water, seed and feed are the basic inputs involved in aquaculture production. Additionally, in an effort to whip up yield, energy is also added to the production process. The combination of all these factors together dictates the product quality and its final value.

In extensive aquaculture systems, large areas are used with low stocking densities. The yield rates are generally meagre. In developing countries, therefore, the method will get gradually replaced by semi-intensive methods for taking optimal benefit of technology potential. Integration of aquaculture with agriculture of livestock raising will also play an important role in such endeavour. Intensive aquaculture is expected to be practised by progressive aquafarmers.

5.3.2 Ranching of Open Waters

Ranching of open waters i.e., enhancement of fisheries by stocking open waters with juveniles of finfishes and shellfishes is a major fisheries developmental agenda of many nations. The technique holds good both for enhancing commercial as well as recreational fisheries. In a country like India, the technique holds immese potential for augmenting production of reservoirs and lakes.

5.3.3 Awakening towards Environment Protection

The impact of aquacultural endeavour on environment will be decisive in determining the growth of aquaculture in coming years. With the current level of waste treatment technology, the treatment of water discharged from land-based aquaculture work out quite expensive. This is largely due to the fact that great amounts of water with very low concentration of nutrients are being discharged. In other words, the quantity of nutrients per unit volume is low but their absolute quantity is high because of the water volume involved. In such a situation, the most appropriate option perhaps would be to make increasing use of used water in aquafarms.

5.3.4 Greater Stress on Sewage-fed Aquaculture

With rising population, disposal of waste, particularly in metropolitan cities, is becoming a problem of major concern. The problem, unless appropriately tackled, is going to become more grave in coming decades. In due appreciation of its serious repercussions; there is a growing awakening towards using aquaculture as a tool for treatment of sewage water. Culture of duckweeds and other macrophytes in sewage water and subsequently its incorporation in finfish/shellfish culture has shown very encouraging results. The system is likely to assume significant importance in the immediate future.

5.3.5 New Candidate Species for Aquaculture

Though the number of species under aquaculture is continuously increasing, aquaculture activities in most countries are dominated by a few species such as carps in China and India, oysters and mussels in Japan, the Republic of Korea and France, milkfish in Philippines and Indonesia and so on. In order to meet the challenges of coming years, the number of aquatic species cultivated and eventually domesticated will increase as new technology becomes available. This will be achieved by intensifying the R & D efforts.

5.3.6 Resorting to Effective Mechanisms for Transfer of Technology

It is often seen that proven aquaculture technologies are not performing well when they are transferred to actual users. This is more so in developing countries. The example of a country like India in this respect stands all the more glaring. Against the demonstration of a new high in carp production of 17.2 tonnes/ha/year, the present national average of carp production stands at 2180 kg/ha/yr covering a water area of 3.87 lakh/ha. The picture obviously testifies the fact that Indian fisheries is a poorly managed sector with a rich resource base. More than anything else the main reason for this is that acute training inputs will be made available to the clientele in a more systematic manner as a consciously and meticulously planned process.

SAQ 2

How sewage fed aquaculture and transfer of technology will help in future development of aquaculture?

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5.4 SUMMARY

In this unit, you have learnt that:

- Aquaculture is growing very rapidly in many countries of the world and is maintaining its position as one of the fastest growing food production channels in the fray. In sharp contrast with the 10,000 year old history of traditional agriculture, inspite of its roots dating back to 4000 years, much of the aquacultural activities have developed only during past 3 to 4 decades.
- The main constraining factors in the growth of aquaculture will be competing usage of available waters such as for recreational activities, conservation of endangered marine mammals and growing industrialization with its resulting pollution.
- Main challenges in aquaculture development are technical challenges, inter-regional cooperation, culture based fisheries, training and marketing.
- In order to realize the potentials of aquaculture in greater measures during the coming decades, the future course of action will include i) shift from extensive to semi-intensive systems of aquaculture, ii) ranching of open waters, iii) greater concern for protecting environment, iv) stress on sewage-fed aquaculture, v) making use of new candidate species for aquaculture, vi) resorting to more effective training input and so on.

5.5 TERMINAL QUESTIONS

1) Describe the major challenges in aquaculture development.

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2) Discuss the future strategies in aquaculture development.

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5.6 ANSWERS

Self-assessment Questions

1. Refer Sec. 5.2
2. Refer Sec. 5.3

Terminal Questions

1. Refer Sec. 5.2.
2. Refer Sec. 5.3.

CONCLUSION

Aquaculture has witnessed a remarkable growth during last few decades with respect to geographical coverage, intensification of farming systems and diversification of culture species and methods. Aquaculture has been considered by the national governments, as well as, by international agencies to play a major role in meeting the increasing demand for fish, prawn, shrimp and other such aquacrops.

Over the past three decades, aquaculture has developed to become the fastest-growing food-producing sector in the world. Aquaculture has expanded, diversified, intensified and advanced technologically and, as a result, its contribution to aquatic food production has also increased significantly. Aquaculture is highly diverse and consists of a broad spectrum of systems, practices and operations ranging from simple backyard, small-household pond systems to large-scale, highly intensive, commercially oriented practices. A large proportion of aquaculture production comes from small scale producers in developing countries and Low Income Food Deficit Countries (LIFDCs).

The world population is on the increase, as is the demand for aquatic food products. Production from capture fisheries at a global level is levelling off, and most of the main fishing areas have reached their maximum potential. Global fish supply could be increased through reduction of discards and better use of by-catch for human consumption, e.g. use of at least part of the catch now going for reduction to fishmeal and fish oils.

However, to meet the challenges of the 21st century and beyond, it appears that aquaculture development will have to rely more on technological refinements rather than on expansion of aquafarm areas. Development of appropriate strains of clones, effective aquafeeds and efficient disease control measures require professional and technical knowledge and skills through innovative research. Aquaculture has to be transformed from “conventional” to modern industrial management.

Even in nations, such as China, Thailand, Philippines, existing professional and technical manpower that have developed technology of aquaculture are grossly inadequate to meet this challenge. The need for such manpower in nations such as Malaysia, Indonesia, India, Bangladesh or Sri Lanka as well as in aquaculturally underdeveloped nations such as Pakistan, Bhutan, Myanmer and Nepal is all the more crucial.

Rapid change is the hallmark of the present era. To cope up with this rapid pace of change, training input has become an indispensable necessity in any sector involved in the economic growth of a nation. This is more so on technological front because with every change in technology, there arises the need for preparing ourselves to acquire the new technical knowhow, lest we are branded “outdated” or “out of place”. Therefore, training is essential for keeping pace with the time. In other words, it implies that effective training is the only option left for keeping pace with the time.

In advanced countries, there is a growing awareness towards looking at training as a continuous process carefully aligned to the changing needs of time. Contrary to this in developing or underdeveloped countries such a perception towards training is frightfully low. In these countries, people are habituated to be content with the conventional training approach which suffers from several limitations such as:

- Not looking into the actual training needs but imparting blanket training.
- Inadequate training facilities and course curricula.
- Training programmes conducted by untrained trainers.
- Training programmes treated as paid holidays by trainees.

- Training considered as a cost, not an investment.

Owing to above limitations, the approach hardly meets the present day needs of training input. The situation, therefore, calls for a drastic change in the outdated approach.

However, it appears that the full potential of the aquaculture sector to contribute to human development and social empowerment is yet to be realized, and the sector may require new approaches to realize its goals beyond 2000. These approaches will undoubtedly differ between different countries, and depend on country-specific circumstances and national development plans, goals and aspirations. The challenge is to develop such approaches, which are realistic and achievable, within the context of current social, economic, environmental and political circumstances.

The essential challenge for future aquaculture development will be to ensure that the full potential of aquaculture is realized, and that a nutritious, safe, high-quality product that is affordable, acceptable and accessible to all sectors of society, is produced. In doing so, we need to address the following needs and opportunities. We have to assist in feeding people in this millennium. This means investing in food security. Aquaculture can play a significant role in this respect.

We have to assist in social development, poverty alleviation and improving the livelihoods of people. In doing so, there is a need to increase emphasis on aquaculture and aqua-farmers in national, social and economic development plans, with the view to enhance institutional and financial support for the sector.

Use of modern information and communication tools and methods such as the Internet and other state-of-the-art communication methodologies will have to be given due consideration, as will the essential requirement to ensure broad-based public access, especially for farmers, to these sources of information.

There is a strong need for greater emphasis on institutional support, that is, support not only to government ministries and public-sector agencies dealing with administration, extension and research and development, but also to organizations and institutions representing the private sector, consumers and other stakeholders.

Aquaculture development, especially if it is to be sustainable for food security goals, may need to be stimulated, at least in the beginning, so there should be a key point on increasing access to credit for farmers, producers and local marketing.

Aquaculture is dependent on key natural resources such as water, land, seed and nutrients. There is strong pressure for production and marketing systems that are more efficient and more effective in terms of resource utilization.

During production, there should be emphasis on targeting the consumers. We must emphasize the difference between mass production and production for the masses. For example, formerly expensive produce such as salmon and shrimp are increasingly becoming affordable to larger segments of the population. We should compete with, and complement, other food-producing sectors and providers.

Environmental and human health issues will slow development or reduce market access. Strategic solutions are required. We should emphasize biosafety issues, development and promotion of biotechnology that conserve the environment.

Aquaculture's potential for social empowerment should be harnessed, and the involvement of more women in aquaculture development should be given due respect.

There are considerable opportunities to increase the impact on aquaculture development through continued regional and interregional cooperation.

In conclusion, it can be summed up that aquaculture will continue to grow because there will be an increased world-wide demand for high quality healthy food. Traditional fisheries, already near maximum production capacity, will be increasingly constrained by competing usage of available waters such as for recreational activities, conservation of endangered marine mammals and industrialization with its resulting pollution. All these could increase greater emphasis on aquaculture.

GLOSSARY

Aquaculture	Aquaculture is the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants, with some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. Farming also implies individual or corporate ownership of the stock being cultivated.
Batch Culture	A system for rearing animals or plants involving the total harvest of the container by netting or draining or both, at a certain interval after stocking
Biomass	The total weight of the organisms contained in as sample or the total weight of organic material present per unit area or volume.
Brackish Water	Any mixture of sea water and fresh water with a salinity of substantially less than 30 parts per thousand (ppt) but greater than 3 ppt.
Cage culture	Rearing of aquatic organisms in enclosures generally constructed of wire or netting as bags supported rigid frames which are floated or suspended in large bodies of water.
Closed System	A water system used for the culture of aquatic animals in which water is reused. Water is added only to replace losses due to evaporation, seepage and so on.
Continuous Culture	A system of rearing animals or plants which involves continuous operation where water and nutrients are provided through an inlet, while culture is harvested continuously through an outlet. The ponds, tanks or containers are not drained for harvesting, nor completely harvested (see Batch culture).
Estuary	A semi enclosed coastal body of water which has a free connection with the open sea and within which seawater is measurably diluted with water derived from land drainage. The low salinity water is called brackish water.
Extensive Aquaculture	Raising aquatic animals or plants under conditions of little or incomplete control over such factors as water flow, number and weight of species raised, and low quality of nutrient inputs.
Fingerlings	Small or juvenile fish, not of marketable size
Fry	The third freshwater stage of salmon development, when the egg mass is no longer present and the fish develops characteristic markings
Grilse	Mature salmonid ready to return to freshwater for spawning after spending one winter at sea.
Incubation	In aquaculture, the holding of eggs from fertilization to hatching
Integrated Aquaculture	Aquacultural systems integrated with livestock and/or crop production. For example, using animal manures to fertilize a pond to enhance fish production and water from the pond to irrigate a garden.

Intensive Aquaculture	Aquaculture practised under a high degree of environmental modification and control in which the principal nutrient source is high-quality feed
Kelt	Spawned fish, usually refers to salmon
Larvae	Immature animals which differ greatly in appearance and behaviour from adults.
Mariculture	The culture of marine organisms
Mixed Culture	The rearing of fish or different age and size, or different species, in the same water body.
Monoculture	The culture of a single species only (opposite of Polyculture)
Nursery	Stage of culture where juveniles are cared for over a few weeks or months before they are released into ponds, cages, etc.
Ocean Ranging	The release of hatchery reared juveniles into the sea for growth to marketable size.
Polyculture	The culture of a number of organisms in the same water body with different food habit (opposite of Monoculture)
Post Larvae	Past the larval stage - a stage which resembles the juvenile but is still lacking some characteristics
Potable Water	Drinking water. Water treated in such a way as to render it suitable for consumption.
Raft Culture	Growing of bivalves on some type of substrate suspended from rafts or floats. The term is sometimes used to describe a method of hanging culture.
Recirculating	Being re-used. Usually refers to water moving through a system and after some form of treatment back into the system.
Recirculating System	Aquaculture system in which at least some of the water is recycled one or more times.
Redd	A bed of gravel in which salmonid lay their eggs
Sea Ranching	The release of juvenile animals to the sea to be captured at the point of release (eg: salmonids).
Semi-closed system	Closed system in which some amount of water is periodically lost or removed, and then replaced.
Smolt	Stage of salmonid that is ready to migrate to the sea
Solar -algae Pond	Transparent or translucent fibreglass cylinder designed as an above-ground tank to maximise phytoplankton production
Spawn	1. Eggs and sperm. 2. To produce or deposit eggs, sperm or young. Usually, but not always applied to aquatic or marine animals
Spawning pond	A specially designed pond where the adult fish can spawn naturally

Stock	A population derived from a number of sources that has not evolved enough to be called a strain.
String Culture	The culture of mussels, scallops, oysters, etc., suspended on ropes or wires from buoys, rafts, etc.
Stripping	Process of artificially removing the eggs and milt from mature fish.

Acronyms & Abbreviations

ALOP	Appropriate Levels of Protection
BMPs	Best Management Practices
CITES	Convention on International Trade in Endangered species of Wild Fauna and Flora
ESD	Ecologically Sustainable Development
FAO	Food and Agriculture Organisation
FCC	Fisheries Co-Management Council.
FRDC	Fisheries Research and Development Corporation
IP	Intellectual Property
IRA	Import Risk Assessment
NAC	National Aquaculture Council.
NADC	National Aquaculture Development Committee.
PBPM	Plant Biosecurity Policy Memoranda
PPM	Abbreviation for parts per million
PPT	Abbreviation for parts per thousand
RAS	Recirculation Aquaculture System.

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